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NASA Contractor Report 152408

(F. J. J. J. J.)

**Study to Develop Improved Fire Resistant
Aircraft Passenger Seat Materials**

(NASA-CR-152408) STUDY TO DEVELOP IMPROVED
FIRE RESISTANT AIRCRAFT PASSENGER SEAT
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**Ames Research Center
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PREFACE

This report is submitted under Contract NAS2-9337. The report covers the period 4 December 1979 through 30 September 1980.

The program was performed at Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach, California. Mr. Fred E. Duskin was Principal Investigator and Program Director at Douglas Aircraft Company and was assisted by the Materials and Producibility Engineering Section.

All data is submitted unpublished, in confidence, to NASA-Ames.

ABSTRACT

The Phase III study of the NASA "Improved Fire Resistant Aircraft Seat Materials" involved fire tests of improved materials in multi-layered combinations representative of cushion configurations. Tests were conducted to determine their thermal, smoke, and fire resistance characteristics. Additionally, a "Design Guideline" for Fire Resistant Passenger Seats was written outlining general seat design considerations. Finally, a three abreast "Tourist Class" passenger seat assembly fabricated from the most advanced fire-resistant materials was delivered to the Ames Research Center.

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SECTION 1

INTRODUCTION

The purpose of this program is to develop an improved fire resistant aircraft seat. The program is divided into four phases. Phase I established a data base with emphasis on thermal characteristics of a wide range of individual seat material candidates. Phase II was concerned with the thermal response of multilayer seat material constructions. Additionally, a preliminary seat specification was written and a source fire was developed. This report covers work accomplished during Phase III which involved continued testing of multilayer seat material constructions, outlining general seat design considerations in a "Design Guideline" for Fire Resistant Passenger Seats, and fabricating a three abreast "Tourist Class" passenger seat assembly from the most advanced fire-resistant materials available. The following Phase IV of this program will encompass the fabrication and full scale burn testing of various seat cushion configurations. Results will be compared to determine the degree of fire resistance achieved by the improved materials and seat designs.

The following report covers all work accomplished in Phase III.

SECTION 2

SYMBOLS AND ABBREVIATIONS

| | |
|--------------------|---|
| av | average |
| BTU | British thermal unit |
| °C | degrees Celsius (centigrade) |
| cc | cubic centimeter |
| cm | centimeter |
| cm ² | square centimeter |
| DAC | Douglas Aircraft Company |
| dm ² | decimeter square |
| °F | degrees Fahrenheit |
| FAA | Federal Aviation Agency |
| FAR | Federal Aviation Requirements |
| ft | feet |
| g/cc | grams per cubic centimeter |
| g/m ² | grams per square meter |
| hr | hour |
| in | inch |
| kg | kilogram |
| kg/cm ² | kilogram per square centimeter |
| kg/m ² | kilogram per square meter |
| kw | kilowatt |
| lb | pound |
| lb/ft ² | pounds per square foot |
| lb/ft ³ | pounds per cubic foot |
| m | meter |
| mm | millimeter |
| min | minutes |
| ml | multilayer (specimen) |
| NASA | National Aeronautics and Space Administration |
| NASA-Ames | National Aeronautics and Space Administration, Ames Research Center |
| N | Newton |
| PBI | Polybenzamidazole |
| psi | pounds per square inch |
| sec | second |
| TC | thermocouple |
| TGA | thermal gravimetric analysis |
| W | watt |

SECTION 3

TESTING OF MATERIALS

Phase III material tests were intended to extend the data base established in Phases I and II. Multilayer tests were extended to incorporate new material. The test methods were basically consistent with those employed in the Phase I and Phase II programs.

3.1 FOLLOW-ON SCREENING TESTS

New materials were screened in accordance with methods described in Appendix A. Results of screening tests on materials included in the Phase III program are summarized in Table 1. The results of TGA testing are shown in Figures 1 through 9. Results of heat release rate tests are shown for individual materials, in Table 2. A list of materials incorporated in Phase III testing and other test data can be found in Appendix B.

3.2 FLOTATION MATERIALS

An early decision was required for selection of a flotation foam recommended by NASA for incorporation in the multilayer test specimens. This decision was necessary to permit early fabrication of test specimens for Phase III and early material procurement for the Phase IV program. Three closed cell polyvinyl chloride foams were considered, and the results of screening tests are reported in Tables 3 and 4. Heat release rate testing results at 3.5 w/cm^2 are reported in Figure 10.

The Airex S 32.5 (414) foam manufactured by Lonza, Inc. was selected.

This selection was made based on several considerations as follows:

1. This foam was significantly lower in weight.
2. The foam met burn requirements.
3. The high smoke number generated was equal to the other vinyls.
4. The material was in the same general range of heat release rate.
5. The material showed no unusual toxicity.
6. The material would be protected by a fire blocking layer and reinforcing layer.

3.3 MULTILAYER TESTS

Multilayer test configurations were negotiated with NASA. The final material combinations are shown in Table 5. These specimens were run at 3.5 w/cm^2 heat flux level [approximate black body temperature of 616°C (1140°F)]. It was felt that higher fluxes would not permit identification of individual differences as they would compress the time for events during testing. The 3.5 w/cm^2 radiant heat flux was still considered to be significantly higher than any small ignition source in terms of thermal threat level. Halfway through the program the baseline urethane foam CS 2850 (322) became unavailable, and the multilayer tests had to be repeated substituting a new baseline urethane foam 2043 FA(324) from North Carolina Foam Industries.

The individual multilayer specimen configurations are shown in Figures 11 and 11A. The new baseline incorporating specimens are identified as the "A" modification.

The results of heat release rate testing are reported for multilayer specimens in Table 6. The results are charted in Figure 12 for ease of comparison. The results may be compared with individual heat release rate testing charted in Figure 13.

TEXTILES 8
(Thermoplastic)

TABLE 1
DATA SUMMARY CHART

| Test & Test Method | Units | ST7427-112 (104) | 20787 Kermel Wool Blend (101) | * 100% Wool Sedellia Blue (117) | * FR Cotton Muslin 44/40 (228) | 400-11 Durette Batt (216) | Nomex III (221) | | |
|------------------------------|-------------------|---------------------------------------|--|---|--|------------------------------------|-----------------------|-----|-----|
| Weight | gm/m ² | 457 gm/m ² | 290 gm/m ² | 407 gm/m ² 12.7oz/yd ² | 158gm/m ² | 362 gm/m ² | 254 gm/m ² | | |
| Thickness | | | | | | | | | |
| Burn Test DMS 1511 | | | | | | | | | |
| Burn Time | sec. | 1 | 0 | 1.3 | 0 | 0 | 0 | 0 | 0 |
| Burn Length | in. | 2.3 | 4.5 | 3.0 | 2.8 | .6 | .7 | 2.3 | 2.6 |
| Drip | | ND | ND | ND | ND | ND | ND | ND | ND |
| NBS Smoke DMS 1500 | | | | | | | | | |
| Nonflaming | 90 sec 4 min | 28 73 | 21 38 | 17 34 | 0 0 | 0 1 | 5 14 | | |
| Flaming | 90 sec 4 min | 64 127 | 21 37 | 52 105 | 0 0 | 6 11 | 0 2 | | |
| Colorfastness Method 5660 | Light | 20SFH | 20SFH | 20SFH40SFH fnt slgt exc exc | - | - | - | | |
| Method 5651(B) | Crocking | exc exc | exc good | | | | | | |
| LOI | | | | | | | | | |
| ASTM D 2863 | warp % fill % | 33 31 | 30 50 | 33 | 48 | 38* | 29 | | |
| TGA Temp of 50% wt loss | °C | 430 | 540 | 425 | 305 | 525 | 570 | | |
| Ignition Pill Test | ASTM 2859 | No burn char in area of pill | No burn char in area of pill | 0.6in Dia x 0.3 in deep Vonar 3/PS | | | | | |

* Phase III data

TABLE 1 (CONTINUED)

DATA SUMMARY CHART

FOAM 8
(Solid Elastomer)

| Test & Test Method | Units | CS2850 * Urethane Foam Reeves Bro (322) | LS200 Neoprene (317) | Ensolite * Type M (412) | Ensolite * Type ALS (413) | FG215 Glass Block (300) | Polyimide 1720-1 Foam 1.5 pcf (323) | Vonar 3/PS Polyester Scrim (229) | Airex S32.5 (414) | 2043 FA Urethane Foam N.C. Ind. (324) |
|---|---|---|---------------------------------|-------------------------------|---------------------------------|----------------------------------|---|---|-----------------------------------|---|
| Density Weight | lbs/ft ³ oz/yd ² | 3.2 | 8.0 | 4.1 | 5.5 | 1.9 - 3.7 | 1.5 | 26.7 | 3.27 | 1.9 10.9 |
| Burn Test DMS 1511 Burn Time Burn Length Drip | sec. in | 0 4.6 0 | 0 1.4 ND | 5 4.7 ND | 0 2.4 ND | 0 2.5 ND | 10 2.7 ND | 0 2.4 ND | 5 5.5 ND | 0 6.0 0 |
| NBS Smoke DMS 1500 Nonflaming Flaming | 90 sec. 4 min. 90 sec. 4 min. | 36 63 52 119 | 27 71 51 122 | - - 223 247 | - - 121 222 | 5 8 4 6 | 0 5 6 16 | 49 90 0 91 148 | >700 >700 | 39 87 47 71 flash |
| Pill Test Ignition ASTM D 2859 | | 10 sec 2 in dia 0.5 in deep | Char in 0.7 inch diameter | | | | 0 sec. 1.12 dia .22 in deep | | 1 in dia x .4 in depth burn | 1.8 in dia .91 in depth |
| LOI | % | 23 | | | | 33 | 36.5 | 30-40 scrim 50-60 foam | 25 | 235 |
| TGA Temp. at 50% wt. loss | °C | 380 | 475 | 440 | 440 | max loss 24% @ 500°C | 570 | 565 | 270 | 290 |
| CORROSION DPS 8.86 | | - | - | - | - | - | - | very slgt corrosion | - | - |

* Phase III data

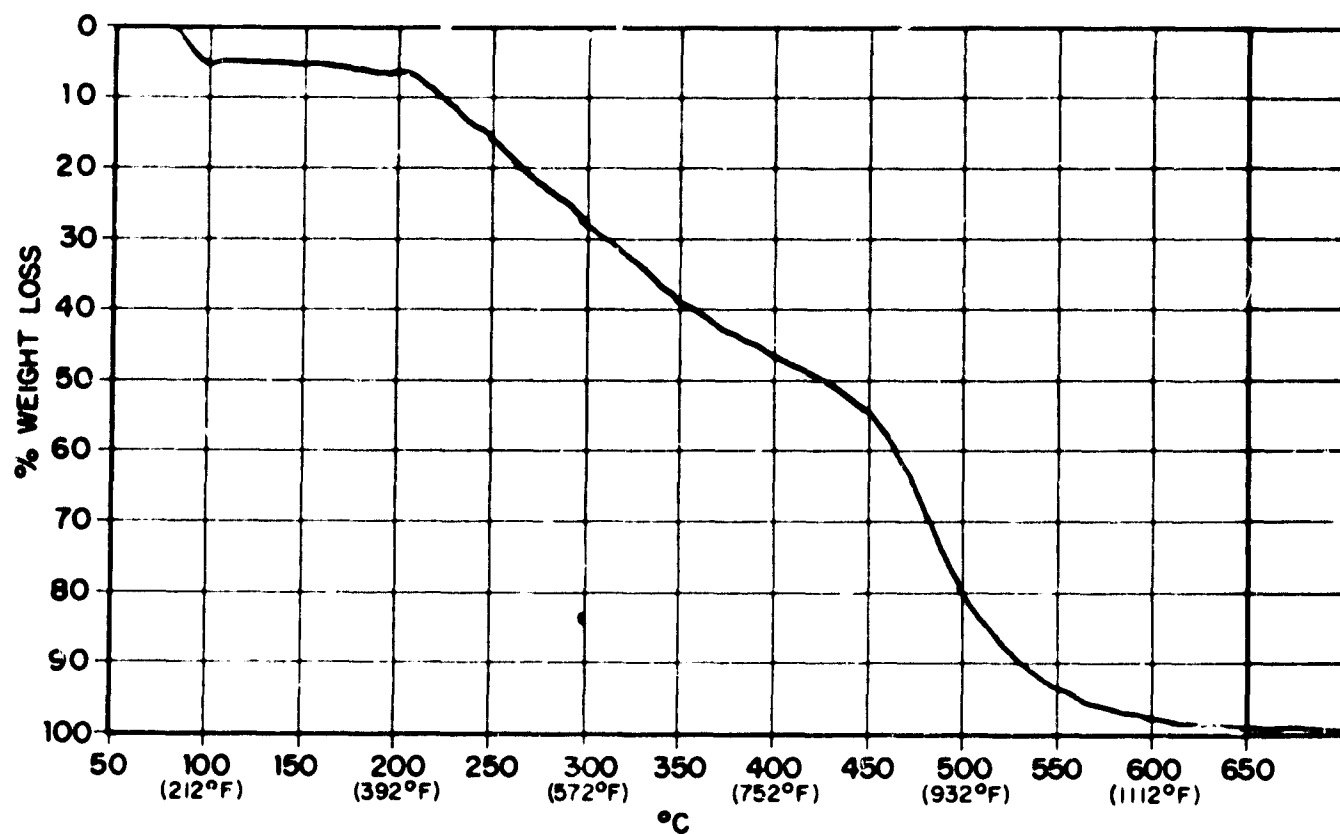


FIGURE 1. TGA CURVE OF SEELLIA 100 PERCENT WOOL (117)

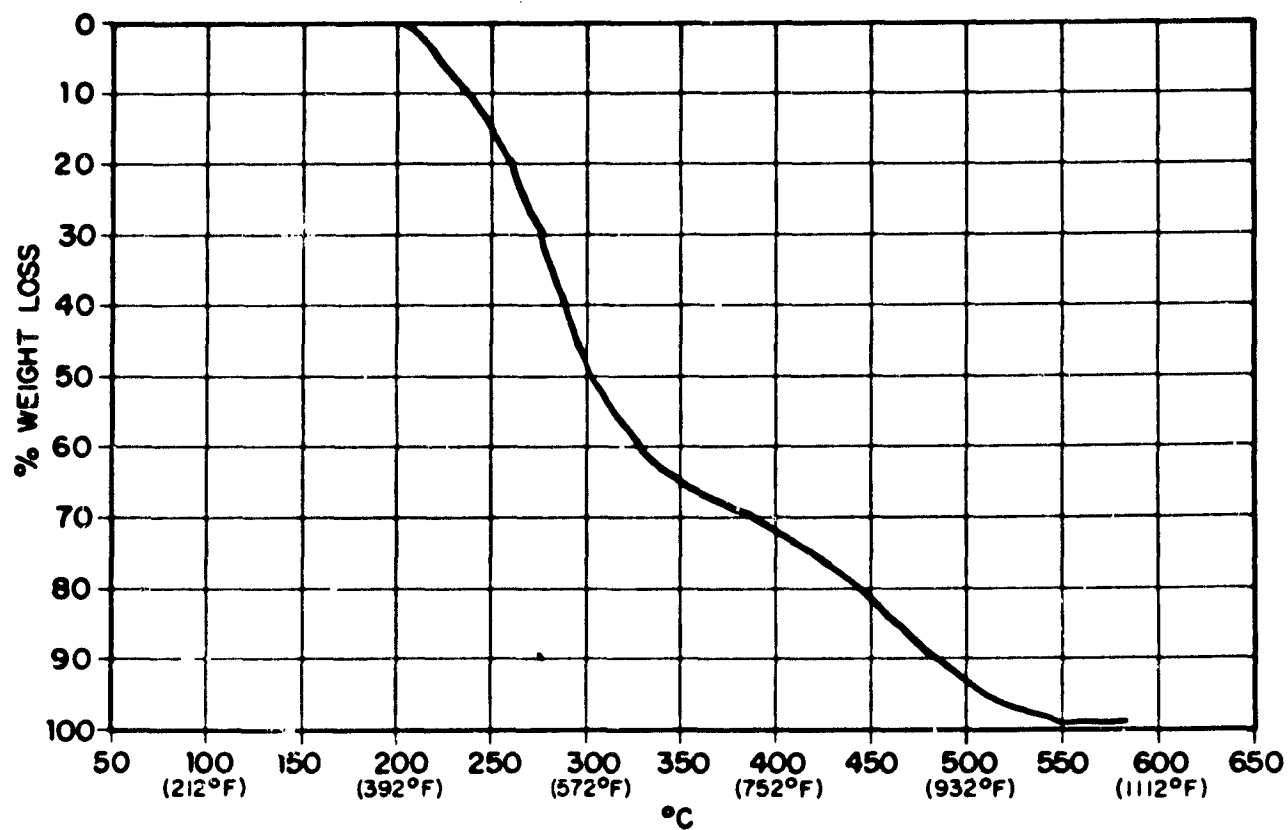


FIGURE 2. TGA CURVE OF COTTON MUSLIN 44/40 CNT (228)

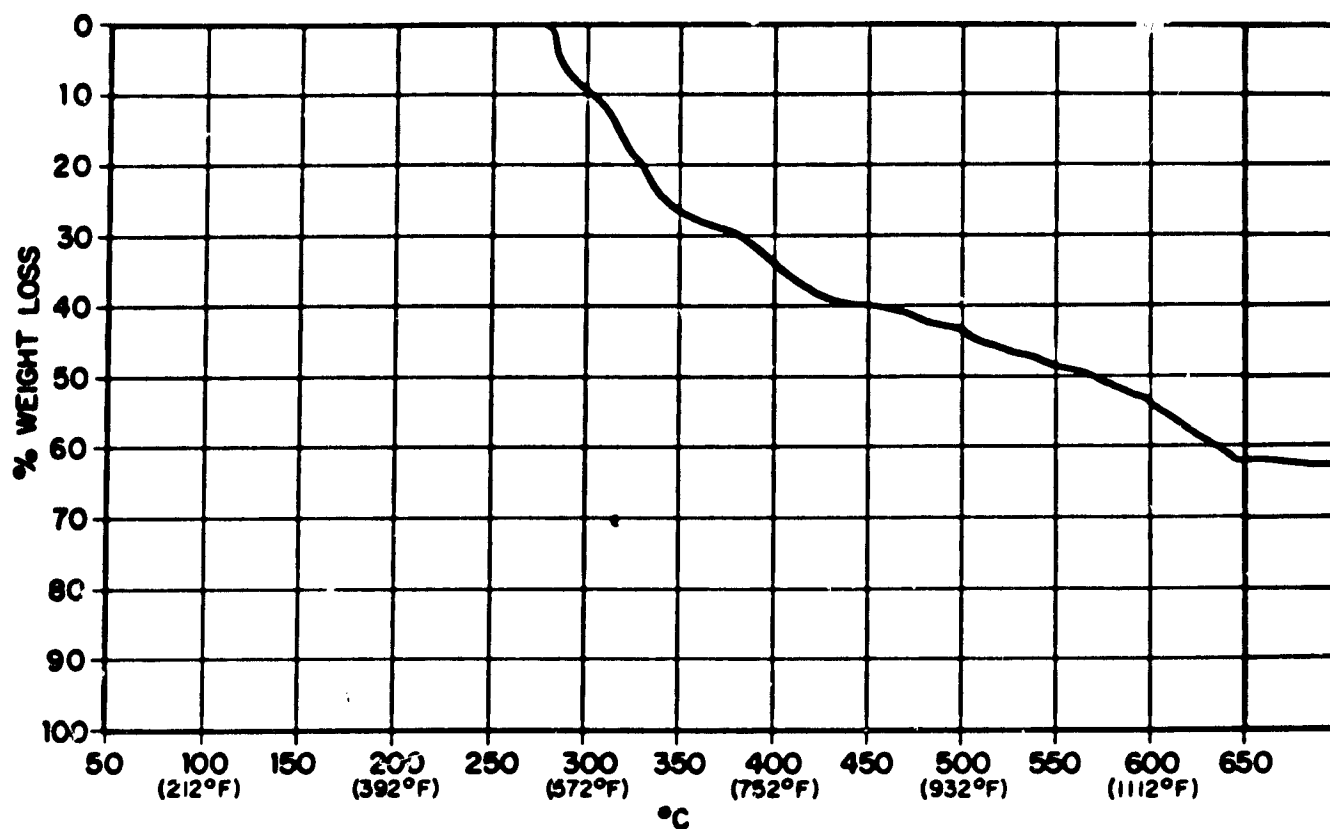


FIGURE 3. TGA CURVE OF VONAR 3/POLYSCRIM (229)

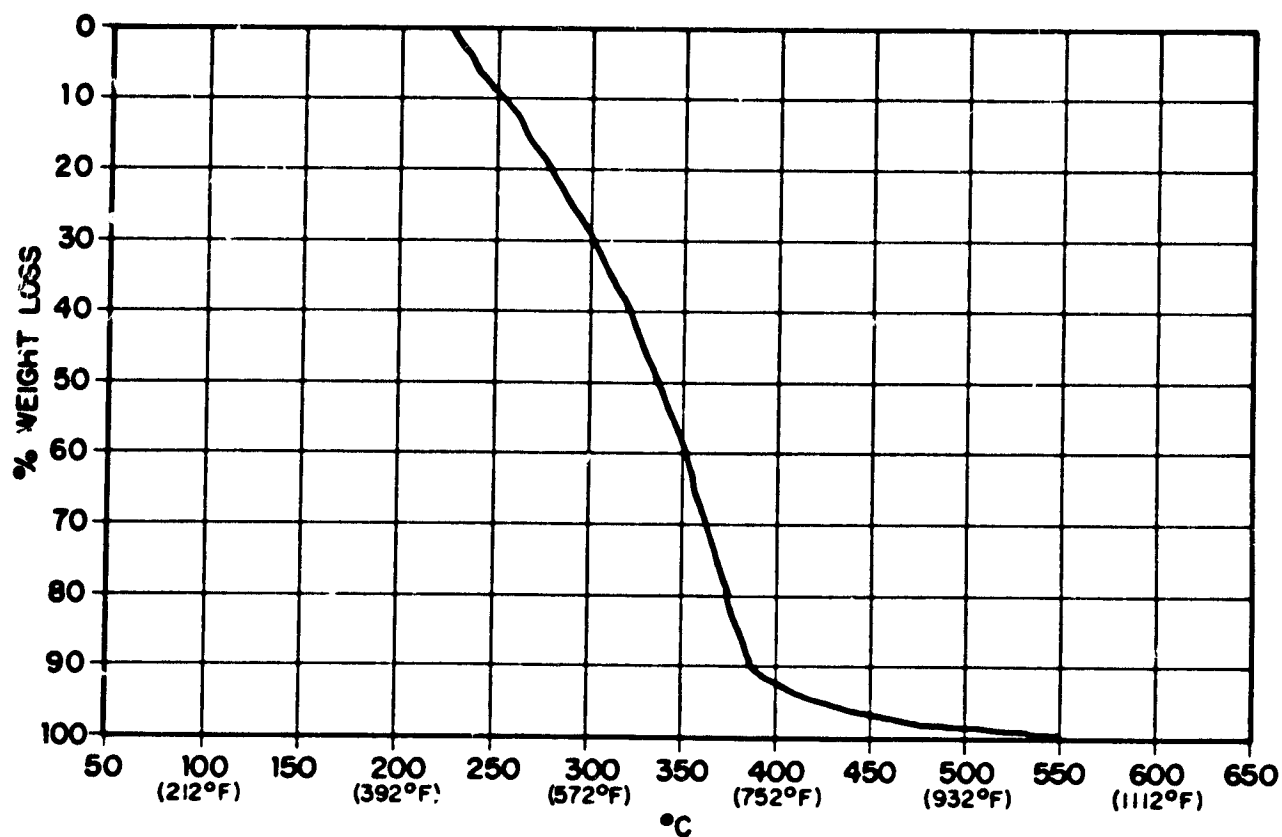


FIGURE 4. TGA CURVE OF URETHANE FLEX FOAM C S2850 (322)

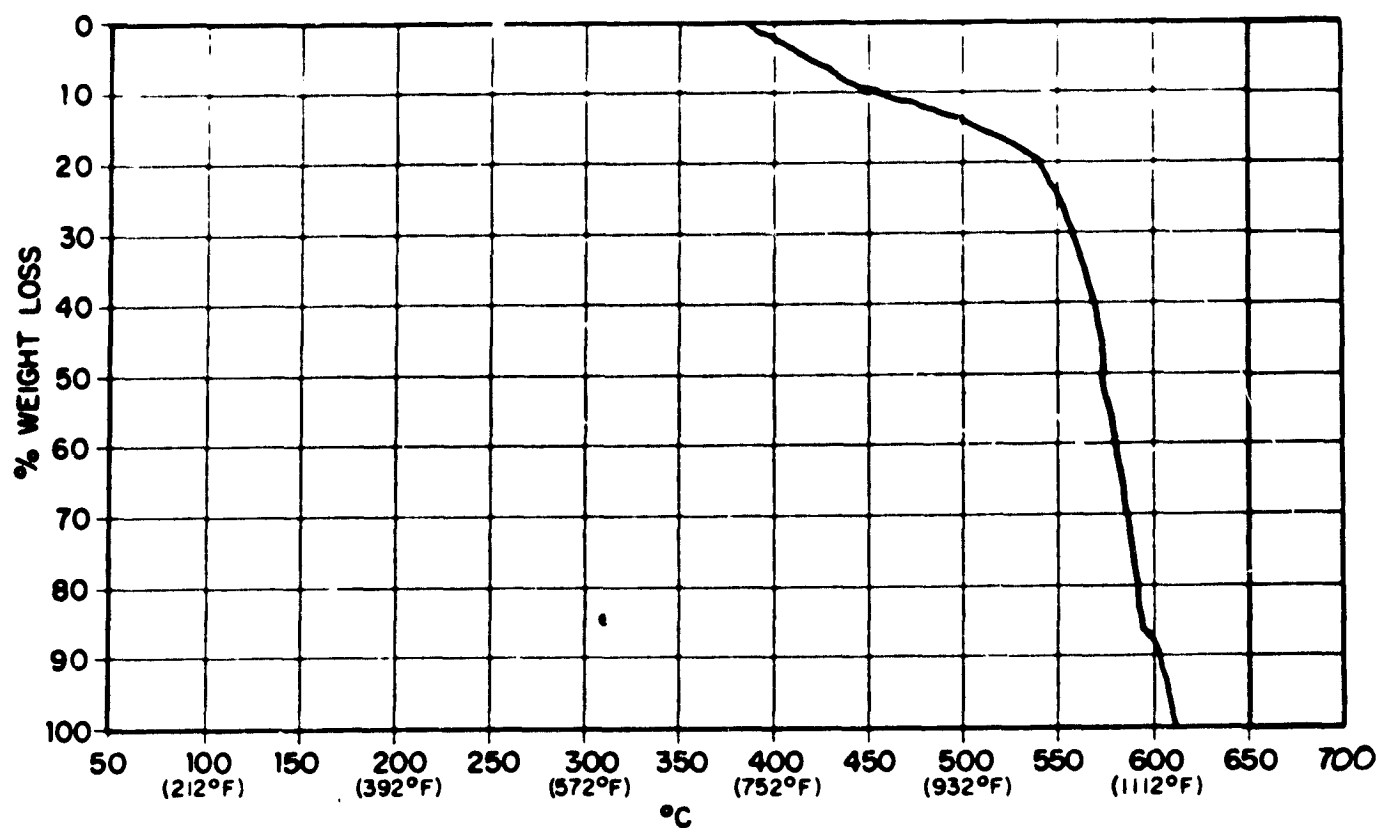


FIGURE 5. TGA CURVE POLYIMIDE FOAM 17-20-1 (323)

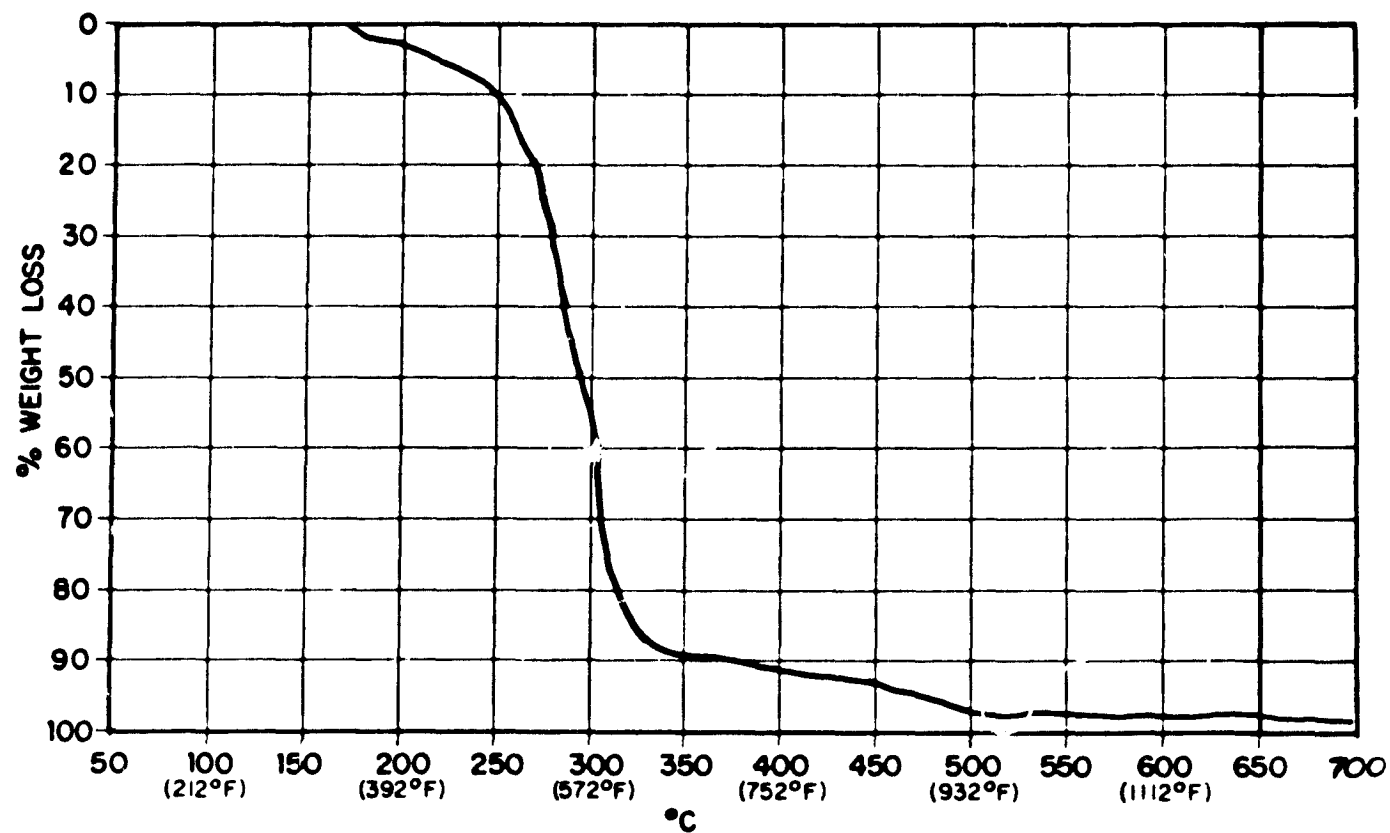


FIGURE 6. TGA CURVE POLYETHER URETHANE (324)

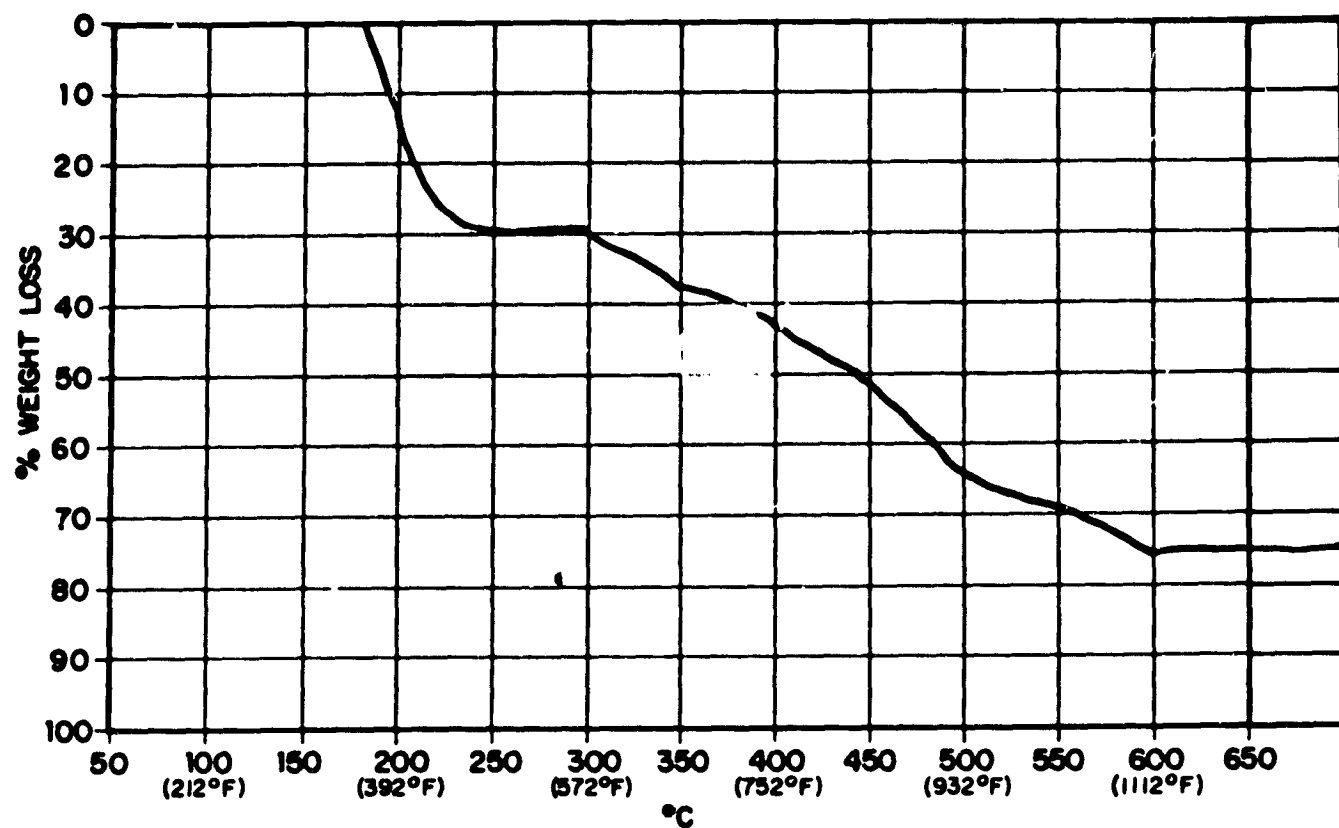


FIGURE 7. TGA CURVE OF ENSOLITE TYPE M (412)

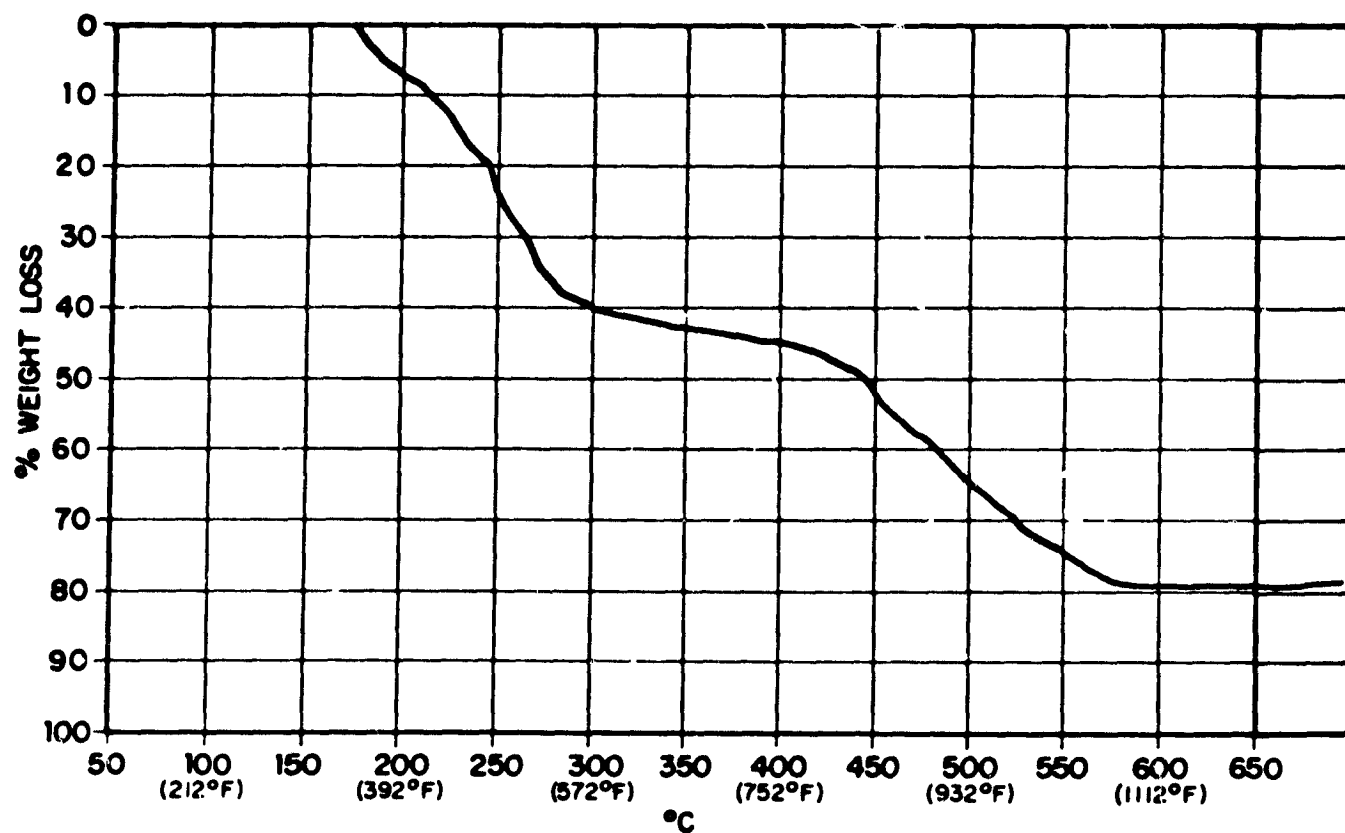


FIGURE 8. TGA CURVE OF ENSOLITE TYPE ALS (413)

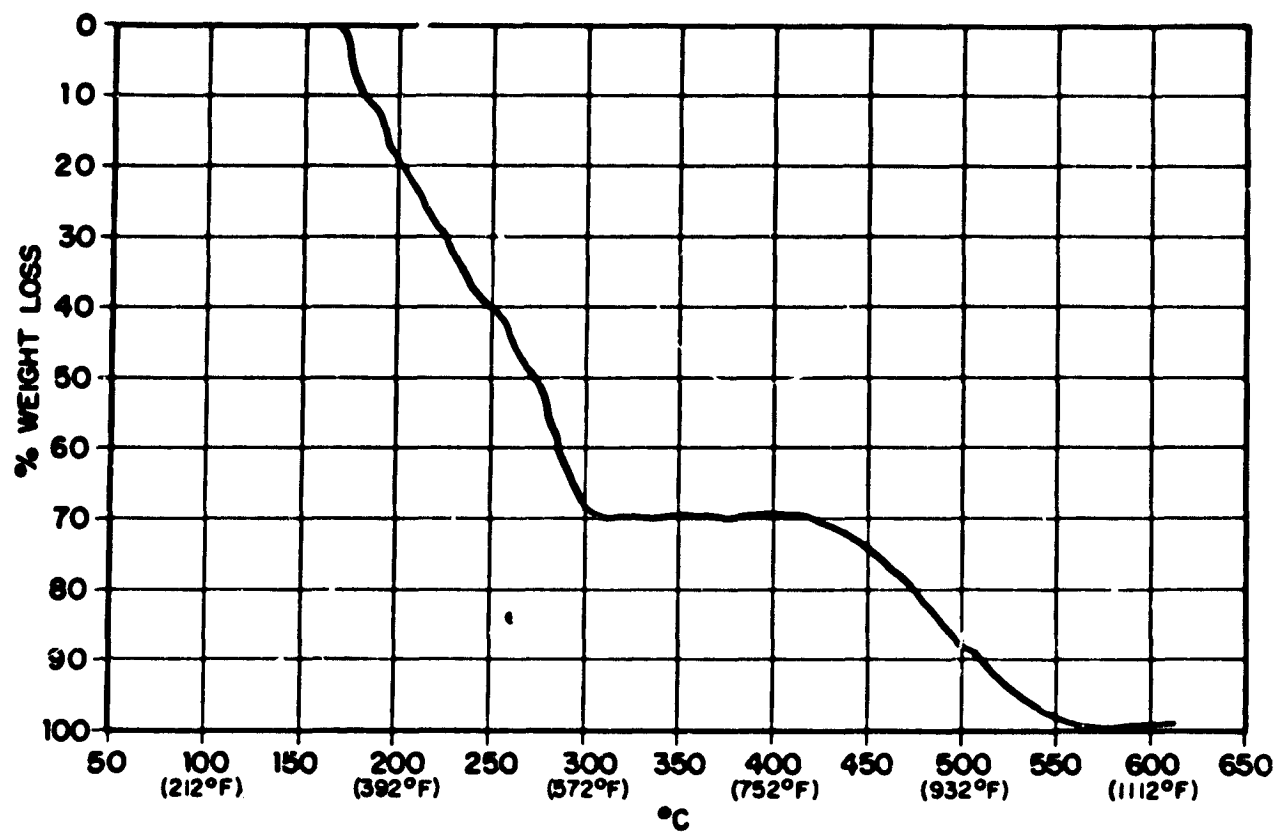


FIGURE 9. TGA CURVE OF AIREX S 32.5 (414)

TABLE 2
INDIVIDUAL MATERIALS

| SAMPLE IDENTIFICATION | HEAT FLUX W/cm ² | TIME TO IGNITION sec. | FLAME TRAVEL RATE mm/sec. | HEAT RELEASE KW - MIN./m ² | | | SMOKE RELEASE SSU/m ² | | | | | | | |
|--|-----------------------------|-----------------------|---------------------------|---------------------------------------|-------------------------|-------------------------|----------------------------------|-------------------------|--|-------------------------|----------------|----------------|----------------|--|
| | | | | MAX. KW/m ² at sec. | TIME INTERVAL - MINUTES | | | | MAX SSU/m ² at sec. | TIME INTERVAL - MINUTES | | | | |
| | | | | | 1.5 | 3.0 | 5.0 | 10.0 | | 1.5 | 3.0 | 5.0 | 10.0 | |
| 20787 Kermel Wool Blend (101) | 2.5 3.5 5.0 | | 2.7 10 ND | | 36 32.6 50.3 | 42.1 41.0 72.9 | 49.4 43.6 102.3 | 65.2 - - | | | | | | |
| ST4727-112 Sun Eclipse Blue (104) Wool/Nylon | 2.5 3.5 5.0 | | 3 >6 6.7 | | 91.8 88.8 85.6 | 115.4 115.6 112.0 | 132.5 130.9 132.0 | 162.8 158.9 160.0 | | | | | | |
| Sedellia Blue 3177 100% Wool (117) | 2.5 3.5 5.0 | <3 <3 Flashed | 7.6 12.7 >30 | | 41 52 60 | 48 63 78 | 53 72 96 | 66 96 132 | 1.3 @ 39sec 40 @ 20sec 9.7 @ 20sec | 1 3 7 | 1 4 11 | 3 5 12 | 8 7 16 | |
| Durette Batt 400-11 (216) | 2.5 3.5 5.0 | | None None None | | 7.3 1.6 8.8 | 16.7 6.3 28.4 | 28.0 13.7 47.4 | 71.7 36.9 - | | | | | | |
| Vonar 3/PS (229) | 2.5 3.5 5.0 | None 80 <3 | None 2.5 1.3 | | -2 -2 13 | -1 8 34 | 6 16 55 | 36 40 106 | 2.8 @280sec 3.8 @113sec 15.8@67.5sec | 1 2 8 | 3 5 16 | 5 6 23 | 9 8 26 | |
| Nomex III (221) | 2.5 3.5 5.0 | None 5 4 | - ~8 ~5 | | -3 3 22 | -3 3 35 | -3 6 54 | -2 22 96 | 7 @ 16 sec 2.5 @ 20sec 12.8@ 8 sec | 8 1 3 | 18 3 4 | 28 4 5 | 71 7 10 | |
| Cotton Muslin 44/40 cnt (228) | 2.5 3.5 5.0 | - <5 <2 | - 6.9 >30 | | 5 7 13 | 10 11 21 | 17 21 33 | 24 45 66 | No measur- able smoke | - - - | - - - | - - - | - - - | |
| LS200 Neoprene (317) | 2.5 3.5 5.0 | None None <2 | None None 12.7 | | -3 4 46 | -1 13 94 | 5 26 129 | 50 80 223 | 1.3 @ 12sec 1.7 @ 12sec 28 @ 11 sec | 1 1 12 | 2 2 20 | 3 2 22 | 6 6 25 | |
| CS2850 Urethane (322) | 2.5 3.5 5.0 | <2 <2 <2 | >10 >15 >20 | | 105 107 104 | 129 132 135 | 147 153 162 | 182 198 218 | 25 @ 10 sec 4.2 @10 sec 65 @ 6 sec | 10 17 18 | 11 18 19 | 12 19 20 | 15 22 22 | |
| FG215 Glass Block (300) | | | | | 6.0 3.2 - | 11.8 8.1 - | 23.2 13.6 - | 35.1 24.6 - | | | | | | |

TABLE 2 (CONTINUED)
INDIVIDUAL MATERIALS

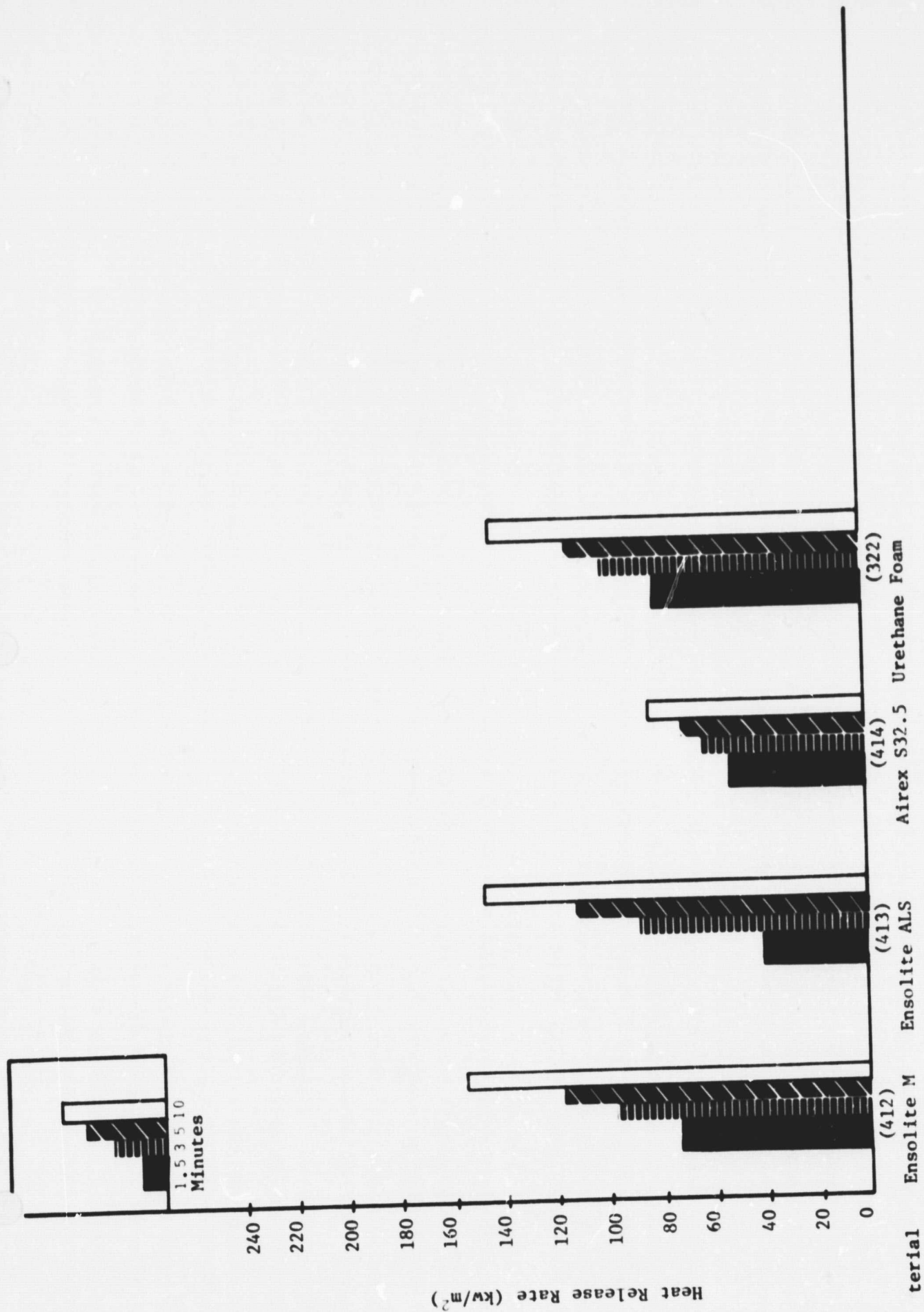
| SAMPLE IDENTIFICATION | HEAT FLUX W/cm ² | TIME TO IGNITION sec. | FLAME TRAVEL RATE mm/sec | HEAT RELEASE KW - MIN./m ² | | | | SMOKE RELEASE SSU/m ² | | | | | |
|---|-----------------------------|-----------------------|--------------------------|---------------------------------------|-------------------------|-----|-----|----------------------------------|-------------------------|-----|-----|-----|------|
| | | | | MAX. KW/m ² at sec. | TIME INTERVAL - MINUTES | | | MAX SSU/m ² at sec. | TIME INTERVAL - MINUTES | | | | |
| | | | | | 1.5 | 3.0 | 5.0 | | 10.0 | 1.5 | 3.0 | 5.0 | 10.0 |
| Ensolute M (412) | 2.5 | <2 | 19 | | 86 | 118 | 132 | 151 | 161@11.3sec | 145 | 147 | 149 | 153 |
| | 3.5 | flashes | >30 | | 101 | 136 | 163 | 217 | 270@11.3sec | 183 | 184 | 185 | 187 |
| | 5.0 | flashes | >30 | | 107 | 145 | 182 | 250 | 353@ 6.5sec | 173 | 174 | 175 | 178 |
| Ensolute ALS (413) | 2.5 | <2 | 7.6 | | 42 | 108 | 135 | 184 | 84@125 sec | 39 | 60 | 62 | 65 |
| | 3.5 | <2 | >15 | | 55 | 123 | 155 | 204 | 118@ 6.3sec | 80 | 116 | 118 | 120 |
| | 5.0 | <2 | >30 | | 67 | 126 | 164 | 236 | 208@ 6.3sec | 149 | 185 | 186 | 190 |
| Airex S32.5 (414) | 2.5 | <3 | >11 | | 81 | 102 | 113 | 131 | 189@27.5sec | 118 | 121 | 122 | 125 |
| | 3.5 | <2 | >30 | | 74 | 99 | 98 | 114 | 308@238sec | 168 | 170 | 172 | 177 |
| | 5.0 | <2 | >30 | | 72 | 91 | 107 | 146 | 35@20 sec | 166 | 167 | 168 | 171 |
| Polyimide Foam 1.5#/ft ³ (323) | 2.5 | None | None | | 1 | 5 | 12 | 34 | 7@ 72 sec | 3 | 3 | 7 | 10 |
| | 3.5 | <2 | 6.4 | | 10 | 20 | 38 | 75 | 1.3@ 15 sec | 5 | 5 | 5 | 6 |
| | 5.0 | <2 | >25 | | 23 | 43 | 74 | 126 | 8.9@7.5 sec | 3 | 4 | 5 | 14 |
| 2043 FA Urethane Foam Baseline (324) | 2.5 | flashes | Melts ~30 | | 68 | 118 | 144 | 188 | | | | | |
| | 3.5 | flashes | Melts ~76 | | 85 | 114 | 135 | 179 | | | | | |
| | 5.0 | flashes | Melts >76 | | 89 | 112 | 131 | 159 | | | | | |
| NOTE: DATA IN THIS TABLE HAVE SAME | | | | BASIS AS PHASES I AND II REPORTS | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

TABLE 3
DATA SUMMARY CHART

| Test & Test Method | Units | Ensolute M (412) | Ensolute ALS (413) | Airex S32.5 (414) | S2850 Urethane Foam (322) |
|---|---|------------------------|--------------------------|--------------------------|------------------------------------|
| Density Weight | lbs/ft ³ oz/yd ² | 3.5 - 5.0 24.5 | 4.5 - 8.5 32.9 | 3.27 | |
| Burn Test DMS 1511 Burn Time Burn Length Drip | sec. in | 5 4.7 ND | 0 2.4 ND | 5 5 5 ND | 0 4.6 ND |
| NBS Smoke DMS 1500 Nonflaming Flaming | 90 sec. 4 min. 90 sec. 4 min. | 223 247 | 121 247 | >700 >700 | 36 63 52 119 |
| Pill Test Ignition ASTM D 2859 | | | | 1 inch dia x .4 depth | 10sec 2 inch dia x .5 depth |
| LOI | % | | | 25 | 23 |
| TGA Temp. at 50% wt. loss | °C | 440 | 440 | 270 | 380 |
| | | | | | |

TABLE 4
RESULTS ANIMAL TOXICITY TESTS

| MATERIAL NO. & NAME | MATERIAL WEIGHT GRAMS | ANIMAL WEIGHT GRAMS | NORMALIZE DATA | | APPARENT MATERIAL PYROLYZED MG |
|---------------------------|-----------------------------|---------------------------|----------------|---------------|---|
| | | | PER GM MATL | 25 GM MOUSE | |
| | | | T1 | Td | |
| <u>Ensolute M</u> | | | | | |
| 2/1 | 0.2481 | 27.7 | 1.27 | - | 143 |
| 2/2 | 0.2537 | 26.4 | .96 | 2.16 | 152 |
| 2/3 | 0.2576 | 24.2 | 1.18 | 2.54 | 145 |
| 2/4 | 0.2768 | 24.2 | 1.37 | 9.89 | 164 |
| AV | | | 1.2 \pm 0.17 | 4.9 \pm 4 | |
| <u>Ensolute ALS</u> | | | | | |
| 1/1 | 0.9802 | 26.6 | 1.43 | 3.68 | 598 |
| 1/2 | 0.2790 | 27.0 | 1.05 | 7.88 | 159 |
| 1/3 | 0.2752 | 23.8 | 1.16 | >9.64 | 154 |
| 1/4 | 0.2742 | 26.2 | 1.20 | 6.22 | 153 |
| AV | | | 1.2 \pm 0.16 | 6.9 \pm 2.5 | |
| <u>Airex Foam</u> | | | | | |
| 3/4 | 0.5292 | 25.3 | 2.74 | 3.88 | 473 |
| 3/5 | 0.5395 | 25.1 | 2.24 | 2.55 | 505 |
| 3/6 | 0.5051 | 25.0 | 2.86 | 5.68 | 458 |
| AV | | | 2.6 \pm 0.33 | 4.0 \pm 1.6 | |




Heat Flux 3.5w/cm²


FIGURE 10. HEAT RELEASE RATE TESTING RESULTS

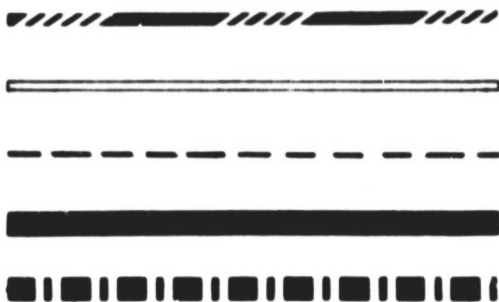
TABLE 5
SEAT DESIGN TEST CONFIGURATIONS


| TEST NUMBER | UPHOLSTERY | FIRE BLOCKING & SLIP COVER | CUSHION REINFORCEMENT (ADHESIVE R2332 N/F) | CUSHION | REMARKS |
|-------------|---|---|--|---|---|
| 1 | ST4727-112 Sun Eclipse Wool/Nylon (104) | None | Cotton Muslin 44/40 Cnt (228) | CS2850 Urethane (322) | Baseline |
| 2 | ST4727-112 Sun Eclipse Wool/Nylon (104) | 400-11 Durette Batt (216) | Nomex III (221) | CS2850 Urethane (322) | Fire Barrier |
| 3 | ST4727-112 Sun Eclipse Wool/Nylon (104) | Vonar 3/PS (229) | Cotton Muslin 44/40 Cnt (228) | CS2850 Urethane (322) | Fire Barrier |
| 4 | 20787 Kermeal/Wool Blend (101) | Nomex III (221) 1/2" LS-200 Neoprene (317) | None | CS2850 Urethane Foam with Airex Foam 32.5 (414) | Fire Barrier and Flotation |
| 5 | 20787 Kermeal/Wool Blend (101) | Nomex III (221) 1/2" LS-200 Neoprene (317) | None | CS2850 Urethane (322) | Fire Barrier |
| 6 | 20787 Kermeal/Wool Blend (101) | None | Nomex III (221) | 1/2" LS-200/Polyimide Foam 1" (323) | Lightweight Combined Cushion |
| 7 | Sedellia Blue 3177 100% Wool (117) | None | Cotton Muslin 44/40 Cnt (228) | Polyimide Foam (323) 1" t | Fire Retardant Cushion |
| 8 | Sedellia Blue 3177 100% Wool (117) | None | Cotton Muslin 44/40 Cnt (228) | Polyimide Foam with Airex Foam 32.5(414) | Fire Retardant Cushion with Flotation |
| 9 | Sedellia Blue 3177 | Vonar 3/PS (229) | Nomex III (221) | FG 215 Glass Batt (300) | Fire Retardant Cushion with Fire Blocking |

- 1)  ST4727-112 Sun Eclipse Blue (104)
Cotton Muslin 44/40 Cnt (228)
Cement
S2850 Urethane Foam (1 inch t) (322)
11 x 11 Area

BASE LINE

NOTE: No cuts material folded at corners
- 2)  ST4727-112 Sun Eclipse Blue (104)
400-11 Durette Batt (216)
Nomex III Fabric (221)
Cement
S2850 Urethane Foam (1 inch t) (322)
11 x 11 Area

NOTE: No cuts material folded at corners
- 3)  ST4727-112 Sun Eclipse Blue (104)
Vonar 3/PS (229)
Cotton Muslin 44/40 Cnt (228)
Cement
S2850 Urethane Foam (1 inch t) (322)

NOTE: No cuts material folded at corners
- 4)  20787 Kermel/Wool Blend (101)
Nomex III Fabric (221)
Cement
LS200 Neoprene Foam (317) 1/2 inch t
Cement
S2850 Urethane Foam (1/2 inch t) (322)
Airex S32.5 (1/2 inch t) (414)

NOTE: Cut at corners except Kermel decorative but all material over cushion edges

FIGURE 11. ML CONSTRUCTION


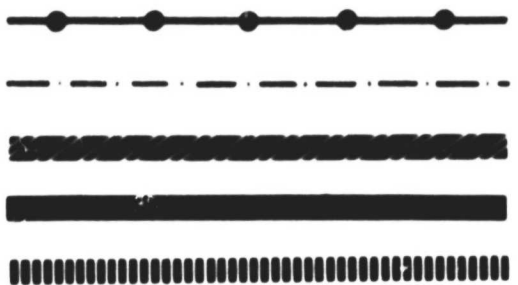
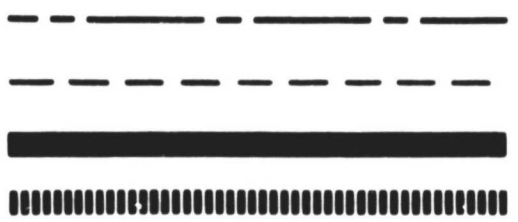
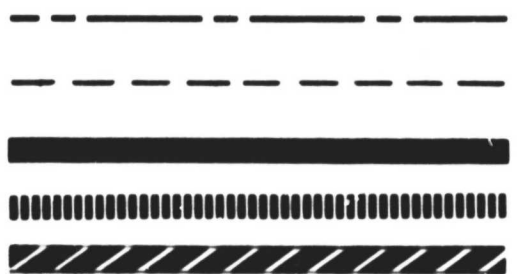
- 5)  20787 Kermel Wool Blend (101)
Nomex III Fabric (221)
LS200 Neoprene Foam (317) 1/2 inch t
Cement
S2850 Urethane Foam 1 inch t (322)
NOTE: LS200 cut at corner & cemented
Nomex III folded only
- 6)  20787 Kermel Wool Blend (101)
Nomex III Fabric (221)
LS200 Neoprene Foam (317) 1/2 inch t
Cement
Polyimide Foam (323) 1 inch t
NOTE: LS200 cut at corner & cemented
Nomex III folded only
- 7)  Sedellia Blue 3177 (117)
Cotton Muslin 44/40 Cnt (228)
Cement
Polyimide Foam (323) 1 inch t
NOTE: No cuts material folded only
- 8)  Sedellia Blue 3177 (117)
Cotton Muslin 44/40 Cnt (228)
Cement
Polyimide Foam (323) 1/2 inch
Airex S32.5 (1/2 inch t) Foam
NOTE: Dam of Polyimide around edge of
Airex

FIGURE 11. ML CONSTRUCTION (CONTINUED)

9)

Sedellia Blue 3177 (117)

=====

Vonar 3/PS (229)

Nomex III Fabric (221)

=====

Cement

■ ■ ■ ■ ■ ■ ■ ■ ■ ■

FG215 Glass Batt Cushion (300) 1 inch t

NOTE: No cuts material folded at corners

FIGURE 11. ML CONSTRUCTION (CONTINUED)

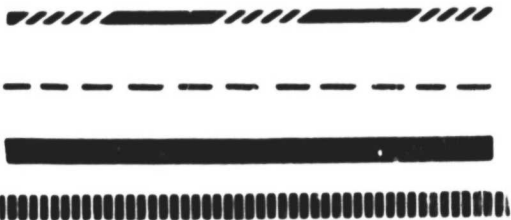
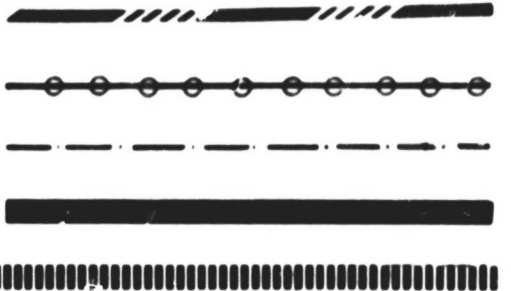
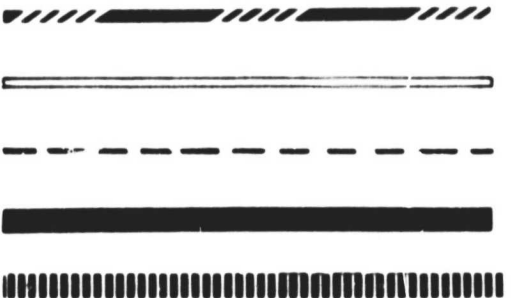
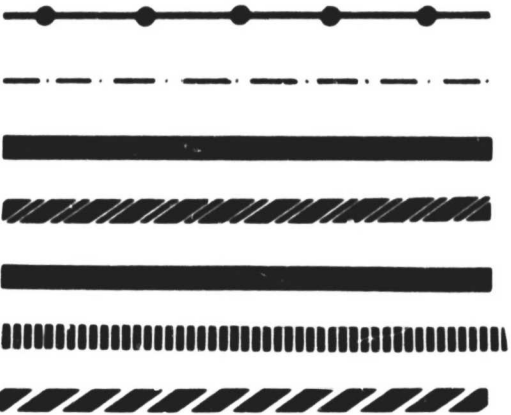
| | | |
|----|---|--|
| 1A |  | ST4727-112 Sun Eclipse Blue (104) Cotton Muslin 44/40 Cnt (228) Cement 2043 FA Urethane Foam (324) 11 x 11 Area |
| | BASE LINE | NOTE: No cuts material folded at corners |
| 2A |  | ST4727-112 Sun Eclipse Blue (104) 400-11 Durette Batt (216) Nomex III Fabric (221) Cement 2043 FA Urethane Foam (324) 11 x 11 Area |
| | | NOTE: No cuts material folded at corners |
| 3A |  | ST4727-112 Sun Eclipse Blue (104) Vonar 3/PS (229) Cotton Muslin 44/40 Cnt (228) Cement 2043 FA Urethane Foam (324) |
| | | NOTE: No cuts material folded at corners |
| 4A |  | 20787 Kermel/Wool Blend (101) Nomex III Fabric (221) Cement LS200 Neoprene Foam (317) 1/2 inch t Cement 2043 FA Urethane Foam (324) Airex S32.5 (1/2 inch t) (414) |
| | | NOTE: Cut at corners except Kermel decorative but all material over cushion edges |

FIGURE 11A. ML CONSTRUCTION

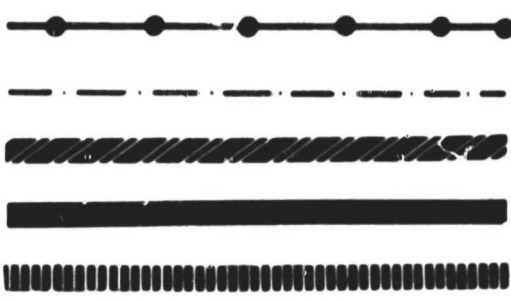
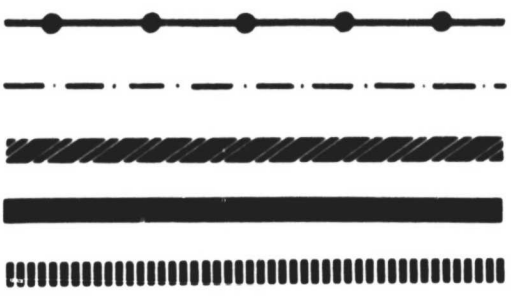

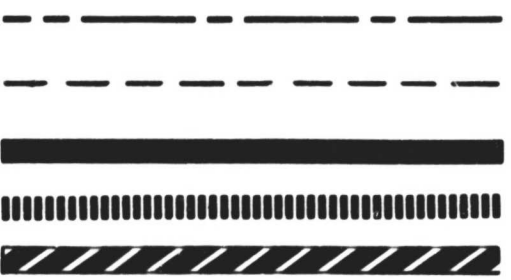
| | | |
|----|---|---|
| 5A |  | <p>20787 Kermel Wool Blend (101)</p> <p>Nomex III Fabric (221)</p> <p>LS200 Neoprene Foam (317) 1/2 inch t</p> <p>Cement</p> <p>2043 FA Urethane Foam (324)</p> |
| | | <p><u>NOTE:</u> LS200 cut at corner & cemented Nomex III folded only</p> |
| 6A |  | <p>20787 Kermel Wool Blend (101)</p> <p>Nomex III Fabric (221)</p> <p>LS200 Neoprene Foam (317) 1/2 inch t</p> <p>Cement</p> <p>Polyimide Foam (323) 1 inch t</p> |
| | | <p><u>NOTE:</u> LS200 cut at corner & cemented Nomex III folded only</p> |
| 7A |  | <p>Sedellia Blue 3177 (117)</p> <p>Cotton Muslin 44/40 Cnt (228)</p> <p>Cement</p> <p>Polyimide Foam (323) 1 inch t</p> |
| | | <p><u>NOTE:</u> No cuts material folded only</p> |
| 8A |  | <p>Sedellia Blue 3177 (117)</p> <p>Cotton Muslin 44/40 Cnt (228)</p> <p>Cement</p> <p>Polyimide Foam (323) 1/2 inch</p> <p>Airex S32.5 (1/2 inch t) Foam</p> |
| | | <p><u>NOTE:</u> Dam of Polyimide around edge of Airex</p> |

FIGURE 11A. ML CONSTRUCTION (CONTINUED)

TABLE 6
HEAT RELEASE TESTS MULTILAYER SPECIMENS

| SAMPLE IDENTIFICATION | HEAT FLUX W/cm ² | TIME TO IGNITION sec. | FLAME TRAVEL RATE mm/sec. | HEAT RELEASE KW - MIN./m ² | | | | SMOKE RELEASE SSU/m ² | | | | | |
|--|--------------------------------|-----------------------------|------------------------------------|---------------------------------------|-------------------------|-----|-----|------------------------------------|-------------------------|-----|-----|-----|------|
| | | | | MAX. KW/m ² at sec. | TIME INTERVAL - MINUTES | | | MAX. SSU/m ² at sec. | TIME INTERVAL - MINUTES | | | | |
| | | | | | 1.5 | 3.0 | 5.0 | | 10.0 | 1.5 | 3.0 | 5.0 | 10.0 |
| ML-1A Wt = 114.9gram (run 14280) (Baseline) | 3.5 | 9 | 9.8 | 121 @ 93 | 108 | 223 | 297 | 396 | 56 @ 27 | 33 | 43 | 43 | 46 |
| ML-2A (run 14180) WT = 152.7 g | 3.5 | 6 | 12.7 | 105 @ 180 | 63 | 153 | 296 | 467 | 37 @ 180 | 6 | 31 | 43 | 44 |
| ML-3A (run 14080) Wt = 200.7g | 3.5 | 6 | 8.5 | 106 @ 186 | 50 | 108 | 266 | 430 | 80 @ 185 | 16 | 61 | 122 | 125 |
| ML-4A (run 11980) Wt = 282.1 g | 3.5 | 9 | 9.8 | 64 @ 443 | 13 | 16 | 22 | 156 | 177 @ 443 | 2 | 4 | 6 | 215 |
| ML-5A (run 14380) Wt = 225.0 g | 3.5 | 2 | 25.4 | 116 @ 234 | 24 | 44 | 216 | 426 | 203 @ 234 | 1 | 6 | 192 | 193 |
| ML - 1 (run 8080) Wt = 142.5 g | 3.5 | 9 | 12.7 | 129 @ 95 | 103 | 241 | 403 | 586 | 63 @ 95 | 43 | 83 | 104 | 110 |
| ML - 2 (run 8180) Wt = 182.4 g | 3.5 | 8 | 12.7 | 124 @ 180 | 61 | 136 | 365 | 651 | 83 @ 160 | 6 | 43 | 116 | 128 |
| ML-3 (run 8580) Wt = 216.8 g | 3.5 | 6 | 11.5 | 122 @ 200 | 49 | 85 | 278 | 546 | 75 @ 197 | 15 | 28 | 109 | 126 |
| ML-5 (run 8480) Wt = 289.3 g | 3.5 | 6 | 7.1 | 100 @ 420 | 17 | 22 | 47 | 423 | 98 @ 420 | 1 | 1 | 11 | 198 |
| ML-6 (run 7880) Wt = 260.3 g | 3.5 | 6 | 7.5 | 32.8 @ 300 | 16 | 22 | 44 | 174 | 12 @ 315 | 1 | 3 | 8 | 21 |

TABLE 6 (CONTINUED)
HEAT RELEASE TESTS MULTILAYER SPECIMENS

| SAMPLE IDENTIFICATION | HEAT FLUX W/cm ² | TIME TO IGNITION sec. | FLAME TRAVEL RATE mm/sec. | HEAT RELEASE KW - MIN. /m ² | | | | | SMOKE RELEASE SSU/m ² | | | | |
|-------------------------------------|--------------------------------|-----------------------------|------------------------------------|--|-------------------------|-----|-----|------|------------------------------------|-------------------------|-----|-----|------|
| | | | | MAX. KW/m ² at sec. | TIME INTERVAL - MINUTES | | | | MAX. SSU/m ² at sec. | TIME INTERVAL - MINUTES | | | |
| | | | | | 1.5 | 3.0 | 5.0 | 10.0 | | 1.5 | 3.0 | 5.0 | 10.0 |
| ML-7 (run 8080) Wt = 92.7 g | 3.5 | 6 | 12.7 | 86 @ 21 | 80 | 141 | 190 | 287 | 21 @ 20 | 9 | 11 | 12 | 14 |
| ML-8 (run 14480) Wt = 348.2 g | 3.5 | 6 | 18.1 | 94 @ 120 | 81 | 197 | 273 | 399 | 132 @ 120 | 27 | 132 | 133 | 134 |
| ML-9 (run 8380) Wt = 219.3 g | 3.5 | 5 | 11.5 | 76.9 @ 245 | 55 | 75 | 186 | 368 | 63 @ 235 | 12 | 13 | 82 | 90 |
| | | | | | | | | | | | | | |
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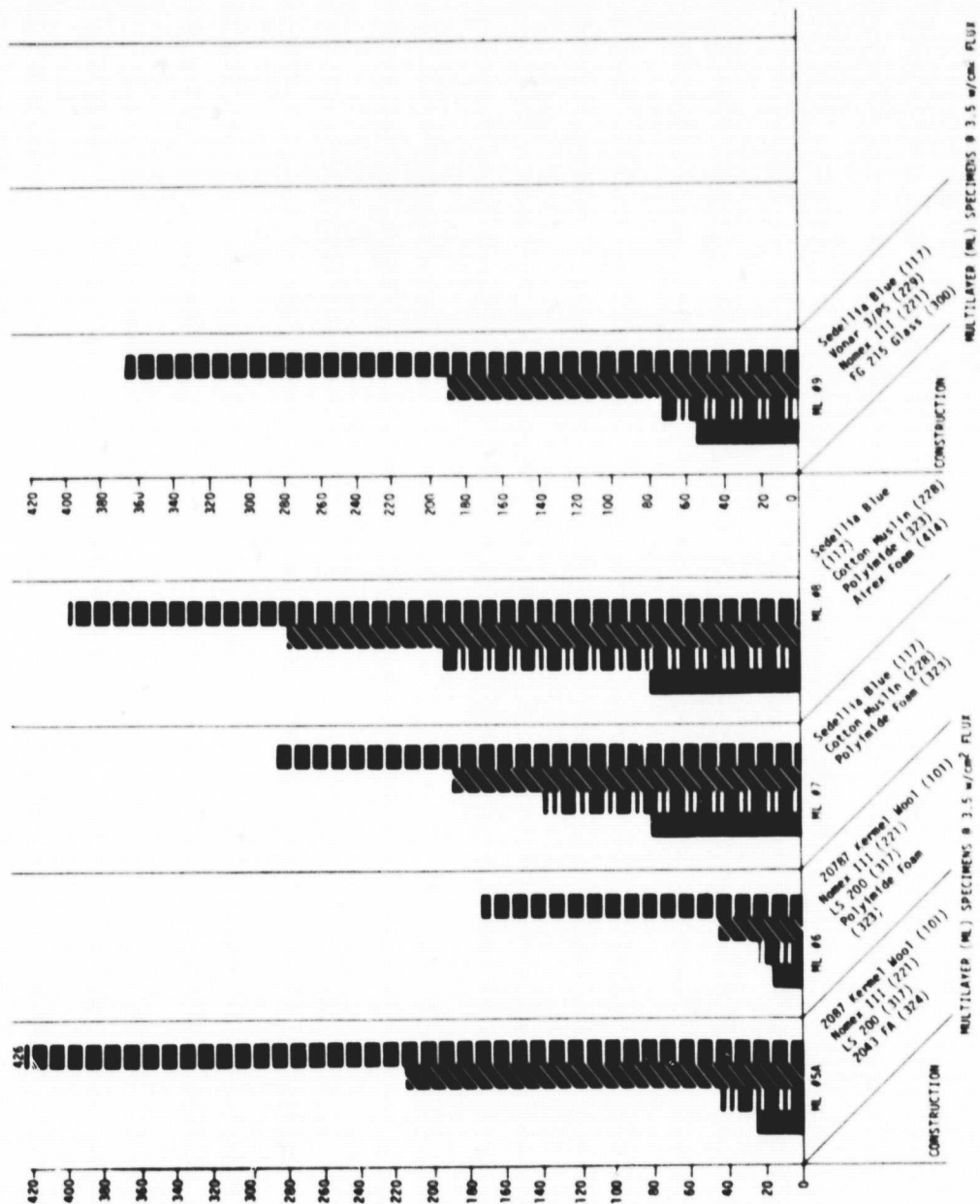


FIGURE 12. MULTILAYER SPECIMEN HEAT RELEASE RATE (CONTINUED)

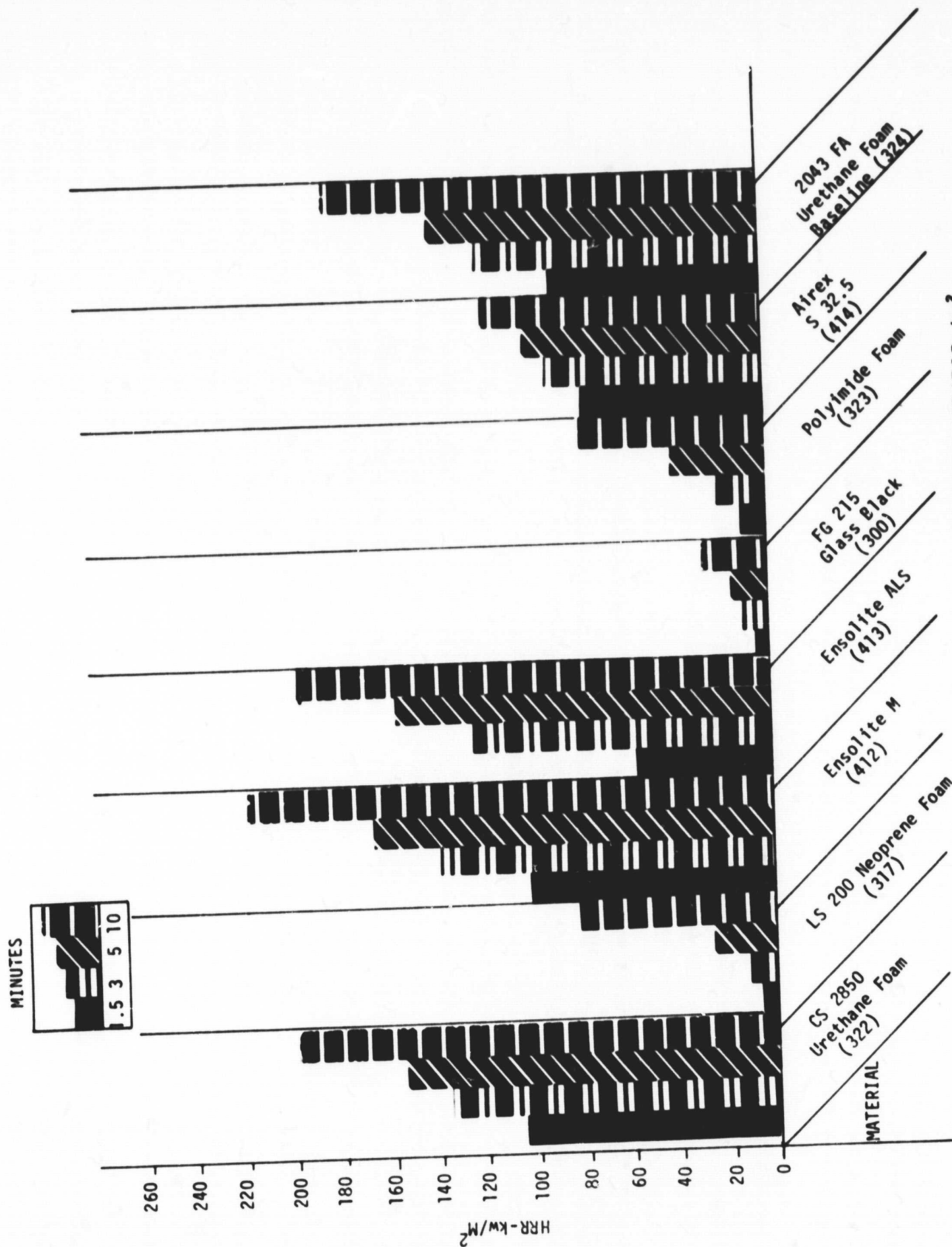


FIGURE 13. INDIVIDUAL MATERIAL HEAT RELEASE RATE AT 3.5 w/cm²

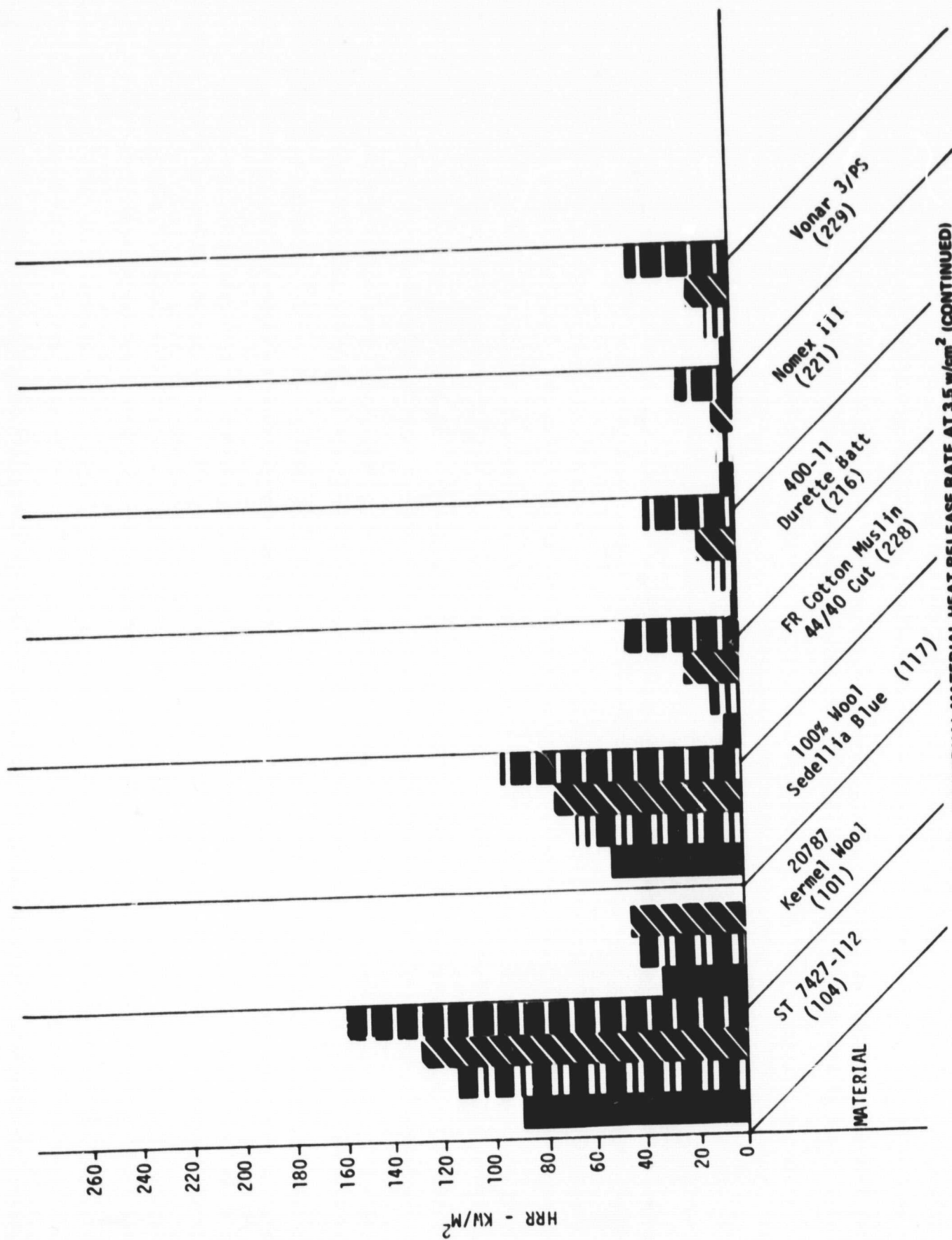


FIGURE 13. INDIVIDUAL MATERIAL HEAT RELEASE RATE AT 3.5 w/cm² (CONTINUED)

SECTION 4

MATERIALS DATA EVALUATION

4.1 DATA EVALUATION

4.1.1 Individual Material Specimens

The Phase II program results showed in Kermel wool (101) to have slightly improved performance when compared to the wool nylon blend (104). The Phase III program results showed the Kermel wool (101) to have slightly improved performance when compared to 100 percent wool Sedellia blue (117) as well. The smoke generation of the Kermel wool was significantly less than the 100 percent wool. TGA temperature at 50 percent weight loss was 540°C for the Kermel wool blend as compared to 425°C for the 100 percent wool.

Of the two slip sheet materials, the Nomex III (221) and FR cotton muslin (228) performance was in the same general range although the TGA temperature at 50 percent weight loss was 570°C for the Nomex III compared to 305°C for the cotton muslin.

The LS200 Neoprene foam (317), the Vonar 3/PS (229) and 400-11 Durette Batt (216) performance, when considered as a fire blocking material, were in the same general range for heat release and other properties except for smoke. The Durette material was significantly lower in smoke generation.

The advanced cushion materials LS200 (317), GF215 (300) and polyimide foam (323), when compared to either of the baseline foams (322,324), show significant improvement in heat release rate properties. They are improved in terms of the rate at which heat is released, which represents a fire spread potential, and in terms of total heat released. Overall, both of the baseline foams performed within a comparable range. The LS200 may serve as fire blocking or cushion material, but its relatively high density will present design challenges when used as cushioning material.

The flotation foams Ensolite M (412), Ensolite ALS (413), and Airex S32.5 (414) performance was in the same general range as the baseline urethanes, both in the rate of heat released and total heat released. The flotation foams do not show improved characteristics and represent a general area requiring thermal resistivity improvement.

4.1.2 Multilayer Material Specimens (Figure 12)

The first five minutes of test basically represent the response of the upper layers for the multilayer specimens other than baseline, where only thermally thin materials of limited resistivity are involved. The reproducibility of testing is shown by comparing upper layers of similar construction during the first five minutes; for example, No's 2 and 2A, No's 3 and 3A, and No's 4A and 5. Poorer reproducibility was obtained for No's 5A and 6. Early release of volatiles from the foam could account for the difference at five minutes.

One of the most significant results is the indication that a fire blocking layer contributes significantly to the reduction in the rate of heat released and to the total heat released even when the cushion material is a baseline urethane foam. This can be seen in comparing No.'s 4A with 6, the latter incorporating an advanced cushion material. This can also be seen when comparing No.'s 5 with 1, which is the baseline with the same foam cushion. While the Vonar 3/PS seems to be less effective in the specific constructions tested compared to LS200, it also improves the urethane performance as can be seen by comparing No.'s 3A with 1A and 3 and 1. It should be noted that the 3/16 inch Vonar was compared with a 1/2 inch LS200.

The protection of the flotation foam by the fire blocking layer can be seen in comparing No.'s 4A and 8.

4.1.3 Summary

The results of the Phase III materials test program may be summarized as follows:

- A. The material data base has been expanded.
- B. The reproducibility of multilayer tests was very good.
- C. The advanced materials continued to perform significantly better under thermal threat than the baseline materials.
- D. Baseline material performance is significantly improved by incorporation of a fire blocking layer.
- E. Additional work is needed to develop flotation material with improved fire resistivity.
- F. The flotation material performance may be improved by use of a fire blocking layer.

4.2 MATERIAL GUIDELINES

Material guidelines have been prepared based on the poorest performance of an advanced material together with allowance for lot-to-lot variation. This latter basis is somewhat arbitrary and would require an expanded test program to become more accurate. The guidelines are only valid in terms of the test methodology specified. Any test variation would require new guideline numbers to be established. The guidelines basically assume that a material meeting the guidelines indicated would perform in a similar manner to the advanced materials tested in the program when exposed to a similar thermal threat. The guidelines would not necessarily pertain to other thermal threats. The guidelines are outlined in Table 7.

TABLE 7
SEAT MATERIAL GUIDELINES

| FUNCTIONAL LAYER | TEST | TEST METHOD | GUIDELINES VALUE |
|---------------------|--------------------|---|--|
| Decorative Fabrics | Colorfastness | FTMS 191 Method 5660 | Minimum good after 20 SFH and 40 SFH |
| | Color Availability | - | Wide range including pastels |
| | Burn Resistance | DMS 1511 | Burn time avg. 5.0 sec max. Burn length avg. 15.24 cm max. Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 40 100 max F 90 sec 4 min 100 150 max |
| | Toxicity | Per method reported in NASA CR-152056 | No unusual toxicity |
| | Abrasion | Wyzenbeck method FTMS 191 method 5304.1 tested against Nomex III S/470 20,000 cycles | 20% max - Loss instrength |
| Slipsheet or Topper | Burn Resistance | DMS 1511 | Burn time avg. 0 sec Burn length avg. 7.6 cm max. Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 10 25 F 90 sec 4 min 10 20 |
| | Toxicity | Per method reported in NASA CR-152056 | No unusual toxicity |
| | Abrasion | Wyzenbeck method per FTMS 191 method 5304.1 tested against ST4727-122 sun eclipse blue 20,000 cycles | 10% max - Loss in strength |
| | | | |
| Fire Blocking | Burn Resistance | DMS 1511 | Burn time avg. 0 sec Burn length avg. 7.6 cm max. Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 55 100 F 90 sec 4 min 100 155 |
| | | | |
| | Toxicity | Per method reported in NASA CR-152056 | No unusual toxicity |

TABLE 7 (CONTINUED)
SEAT MATERIAL GUIDELINES

| FUNCTIONAL LAYER | TEST | TEST METHOD | GUIDELINE VALUE |
|---------------------------|-------------------|--|--|
| Fire Blocking (Cont'd) | Abrasion | Wyzenbeck method per FTMS 191 Method 5304.1 Tested against 10,000 cycles | 50% Max - Loss in strength |
| | Heat Release Rate | Per method reported in NASA CR-152056 | @ 3.5w/cm ² Max @ 1.5 min = 6 kw/m ² 3.0 min = 18 kw/m ² 5.0 min = 35 kw/m ² |
| | TGA | @ 20°C per minute in air | Max Wt. 80% Loss % Temp @ 50% 560°C Wt loss |
| Cushion Reinforcement | Burn Resistance | DMS 1511 | Burn time avg. 0 sec max. Burn length Avg. 8.9 cm max. Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 10 15 max F 90 sec 4 min 5 7 max |
| | Toxicity | Per method re- ported in NASA CR-152056 | No unusual toxicity |
| | Tear | FTMS 191 Method 5132 | 8.0 kg min |
| Cushion | Burn Resistance | DMS 1511 + Modified DMS 1511 for metling material | Burn time avg. 6 sec max. Burn length avg. 15.2 cm max. Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 35 80 max F 90 sec 4 min max. 55 132 |
| | Toxicity | Per method reported in NASA CR-152056 | No unusual toxicity |
| | Heat Release Rate | Per method reported in NASA CR-152056 | @ 3.5 w/cm ² Max @ 1.5 min = 18 kw/m ² 3.0 min = 28 kw/m ² 5.0 min = 48 kw/m ² |

TABLE 7 (CONTINUED)
SEAT MATERIAL GUIDELINES

| FUNCTIONAL LAYER | TEST | TEST METHOD | GUIDELINE VALUE |
|------------------------|-----------------------------------|--|---|
| Cushion (Cont'd) | TGA | @ 20 C per minute in air | Max Wt Loss % = 75 Temp @ 50% = 470°C |
| | Indentation and Deflection | ASTM D240G Method A | @ 25% 18.2 kg min |
| | Compression Set | ASTM D 1055 Method 19.1 | Increase @ 50% Defl = 10% max |
| | *Density | ASTM D1564 | .14 gm/cc (1 lbs/ft ³) max. |
| | Burn Resistance | DMS 1511 | Burn time avg. 6 sec max. Burn length avg. 15.2 cm max. Drip ND |
| Cushion Flotation Core | Heat Release Rate | Per method reported in NASA CR-152056 | @ 3.5 w/cm ² Max @ 1.5 min = 115 kw/m ² 3.0 min = 148 kw/m ² 5.0 min = 180 kw/m ² 10.0 min = 225 kw/m ² |
| Thermoplastic Shrouds | Burn resistance .043 thickness | DMS 1511 | Burn time avg. 0 sec max Burn length avg. 4.0 cm Drip ND |
| | Smoke | DMS 1500 | NF 90 sec 4 min 4 sec 25 max F 90 sec 4 min 75 200 max |
| | Toxicity | Per method reported in NASA CR-152056 | No unusual toxicity |
| | TGA | @ 20°C per minute in air | Max wt Loss T 98 Temp @ 50% 505°C min Wt Loss |
| Thermoset Seat Bottom | Burn Resistance | DMS 1510 | Burn time avg. 1 sec max, Burn length avg. 5 cm max. Drip ND |

*See discussion

TABLE 7 (CONTINUED)
SEAT MATERIAL GUIDELINES

| FUNCTIONAL LAYER | TEST | TEST METHOD | GUIDELINE VALUE |
|-----------------------------------|-----------------|-------------|------------------------------|
| Thermoset Seat Bottom (Cont'd) | Smoke | DMS 1500 | NF 90 sec 4 min |
| | | | 25 50 max |
| | | | F 90 sec 4 min |
| | | | 25 50 max |
| Hardware Components | Burn Resistance | DMS 1510 | TGA |
| | | | % wt Loss Max |
| | | | Burn time avg. 15 sec max |
| | | | Burn length avg. 15.2 cm max |
| | | | Drip ND |

SECTION 5

ECONOMIC ANALYSIS

The cost impact of manufacturing aircraft passenger seat cushions from fire resistant materials/constructions cannot be reasonably determined until a production order of a particular design is produced. It may be safe to assume that the manufacturing costs would increase in comparison to present construction practices. Additional labor would be required to produce the multilayered constructions and new cutting die templates would be needed for cutting the multilayers.

Finally, major manufacturing problems are not anticipated for fire resistant material substitutions.

5.1 MATERIAL COSTS AND WEIGHTS

The cost and weights of individual seating materials are presented in Table 8. Using these values, a cost and weight estimate for material usage was performed on each of the Seat Design Test Configurations listed in Table 9.

The cost results are presented in Figure 14. Figure 14 shows all configurations costing more than the baseline seat (No. 1). A cost for polyimide foam was not available.

The weight results are presented in Figure 15. Figure 15 shows that the seat configuration using the polyimide foam cushion (No. 7) would produce a weight savings in comparison to the baseline seat. All other cushion configurations would result in a weight increase.

With the cost values of polyimide foam unavailable for comparison, the cushion configuration using a fire blocking layer of Vonar 3/PS protecting a urethane foam cushion appears the most appealing candidate when considering cost in cushion design.

TABLE 8
MATERIAL ECONOMICS

| MATERIAL | WEIGHT | PRICE 1980 \$ |
|---|--|--|
| ST4727-112 SUN ECLIPSE WOOL/NYLON (104) | 456 g/m ² (0.84 LB/YD ²) | 14.14/m ² (17.95/LIN YD) |
| 20787 KERMEL/WOOL BLEND (101) | 293 g/m ² (0.54 LB/YD ²) | 24.8/m ² (20.78/YD ²) |
| SEDELLIA BLUE 3117 100 PERCENT WOOL (117) | 408 g/m ² (0.75 LB/YD ²) | 15.76/m ² (20.00/LIN YD) |
| COTTON MUSLIN 44/40 Count (228) | 158 g/m ² (0.29 LB/YD ²) | 0.59/m ² (0.75/LIN YD) |
| 400-11 DURRETTE BATT (216) | 364 g/m ² (0.67 LB/YD ²) | 14.97/m ² (19.00/LIN YD) |
| VONAR 3/PS (229) | 831 g/m ² (1.53 LB/YD ²) | 2.81/m ² (3.19/YD ²) |
| NOMEX ITT (221) | 255 g/m ² (0.47 LB/YD ²) | 9.64/m ² (12.23/LIN YD) |
| 2043 FA URETHANE (324) | 32 kg/m ³ (2.0 LB/FT ³) | 169.48/m ³ (4.80/FT ³) |
| AIREX S32.5 (414) | 52 kg/m ³ (3.27 LB/FT ³) | 402.53/m ³ (11.40/FT ³) |
| LS 200 NEOPRENE (317) | 128 kg/m ³ (8.0 LB/FT ³) | 635.58/m ³ (18.00/FT ³) |
| POLYIMIDE (223) | 24 kg/m ³ (1.5 LB/FT ³) | |
| FG 215 GLASS BLOCK (300) | 44.94 kg/m ³ (2.8 LB/FT ³) | 1758.44/m ³ (49.80/FT ³) |

TABLE 9
FINAL SEAT DESIGN TEST CONFIGURATION

| TEST NUMBER | UPHOLSTERY | FIRE BLOCKING | CUSHION REINFORCEMENT (ADHESIVE R2382 N/F) | CUSHION | REMARKS |
|----------------|---|---|--|--|--|
| 1 | ST4727-112 Sun Eclipse Wool/Nylon (104) | None | Cotton Muslin 44/40 Cnt (228) | 2043FA Urethane (324) | Baseline |
| 2 | ST4727-112 Sun Eclipse Wool/Nylon (104) | 400-11 Durette Batt (216) | Nomex III (221) | 2043FA Urethane (324) | Fire Barrier |
| 3 | ST4727-112 Sun Eclipse Wool/Nylon (104) | Vonar 3/PS (229) | Cotton Muslin 44/40 Cnt (228) | 2043FA Urethane (324) | Fire Barrier |
| 4 | 20787 Kermel/Wool Blend (101) | Nomex III (221) 1/2" LS-200 Neoprene (317) | None | 2043FA Urethane Foam with Airex (414) Core | Fire Barrier and Flotation |
| 5 | 20787 Kermel/Wool Blend (101) | Nomex III (221) 1/2" LS-200 Neoprene (317) | None | 2043FA Urethane (324) | Fire Barrier |
| 6 | 20787 Kermel/Wool Blend (101) | None | Nomex III (221) | 1/2" LS-200/ Polyimide Foam | Lightweight Combined Cushion |
| 7 | Sedellia Blue 3177 100% Wool (117) | None | Cotton Muslin 44/40 Cnt (228) | Polyimide Foam (323) | Fire Retardent Cushion |
| 8 | Sedellia Blue 3177 100% Wool (117) | None | Cotton Muslin 44/40 Cnt (228) | Polyimide Foam Airex (414) Core | Fire Retardent Cushion with Flotation |

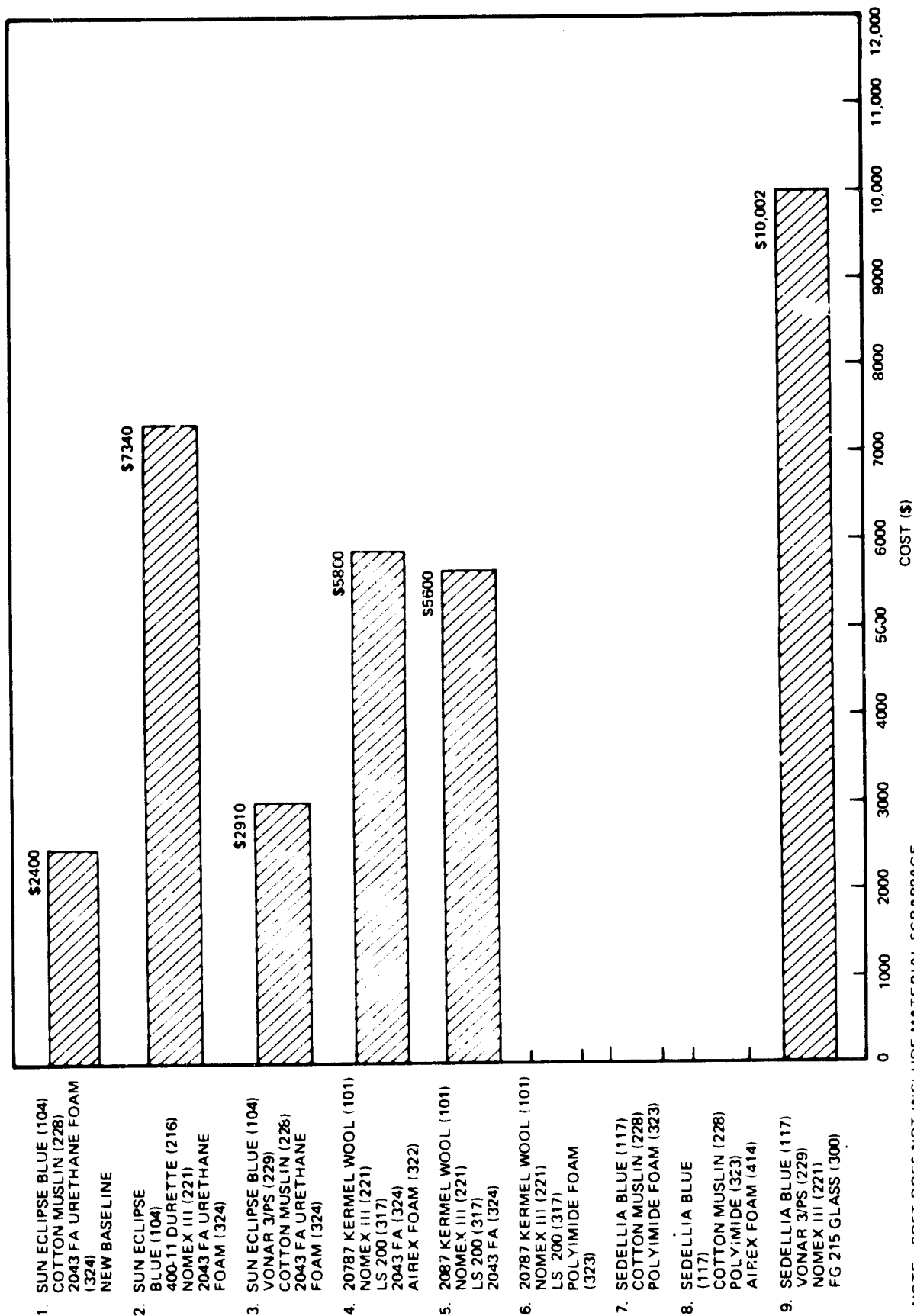


FIGURE 14. COST/100 CUSHION SETS (BOTTOM AND BACK)

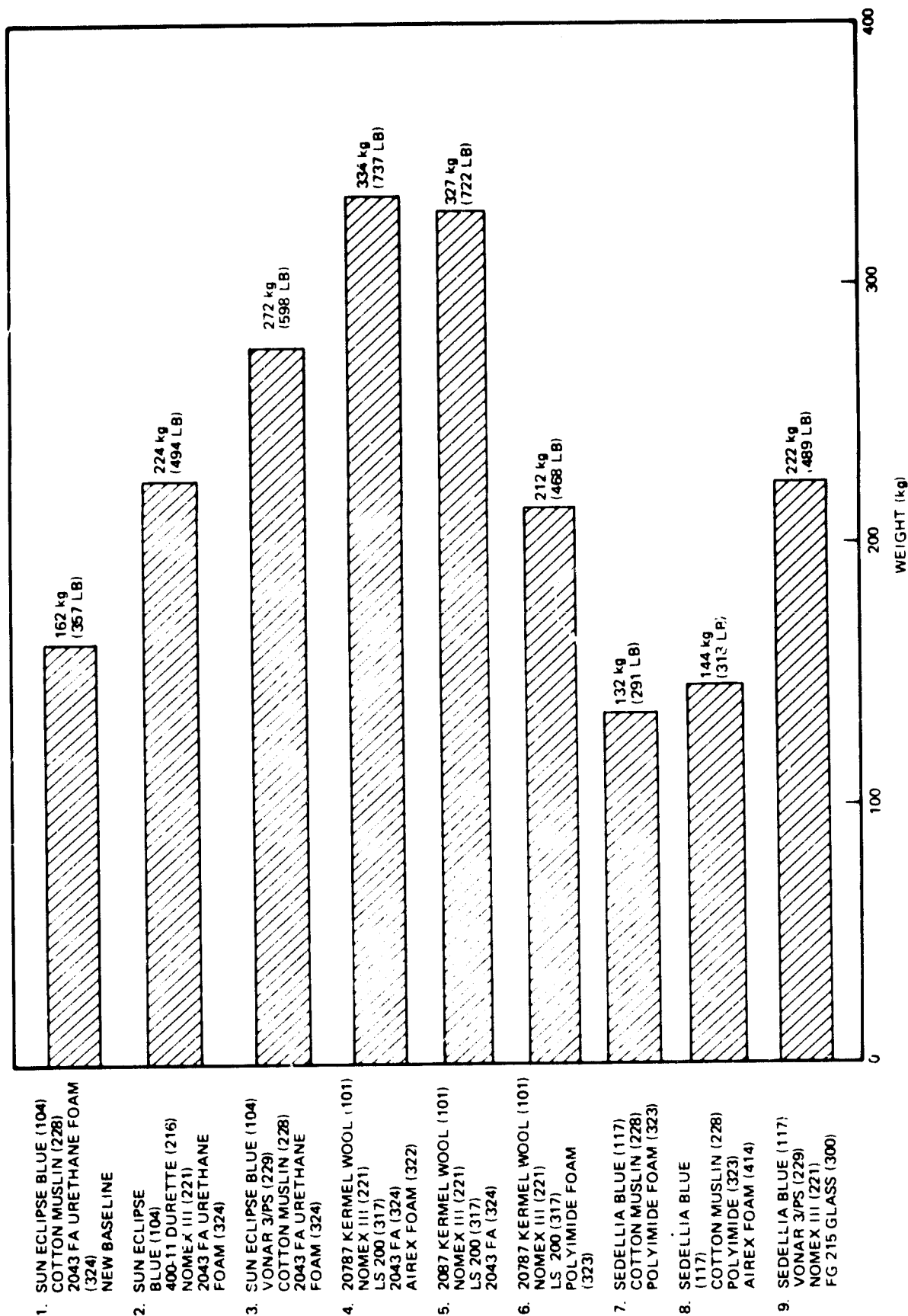


FIGURE 15. WEIGHT ESTIMATE/100 CUSHION SETS (BOTTOM AND BACK)

SECTION 6

DESIGN GUIDELINE — FIRE RESISTANT SEATS

The following information is provided as a guideline that may be consulted for material and design considerations for improvement of aircraft passenger seat fire resistance.

Those seat components explored are listed below:

- o Structural Frame
- o Recline Mechanism
- o Decorative Shrouds
- o Armrests
- o Food Trays
- o Structural Fire Barriers
- o Literature Pocket
- o Seat Cushions

6.1 STRUCTURAL FRAME (Figure 16)

In studying the structural framework of different passenger seats, it has shown that very little may be done to improve its fire resistance. However, later in this guide, it will be noted that some of the materials used in the cushion construction could greatly increase the weight of the aircraft. It would, therefore, be advantageous to explore seat structure that would be lightweight without sacrificing structural strength in order to compensate for the additional cushion weights. Determining structural designs is beyond the scope of this program and will not be discussed further.

6.2 RECLINE MECHANISMS (Figure 17)

The major concern in a recline mechanism design is to prevent a seat back from inadvertently reclining during a fire.

There are three areas where the recline mechanism may become nonfunctional due to heat from fire. These areas are attachments to the seat frame and seat back, cylinder casing, and internal seals.

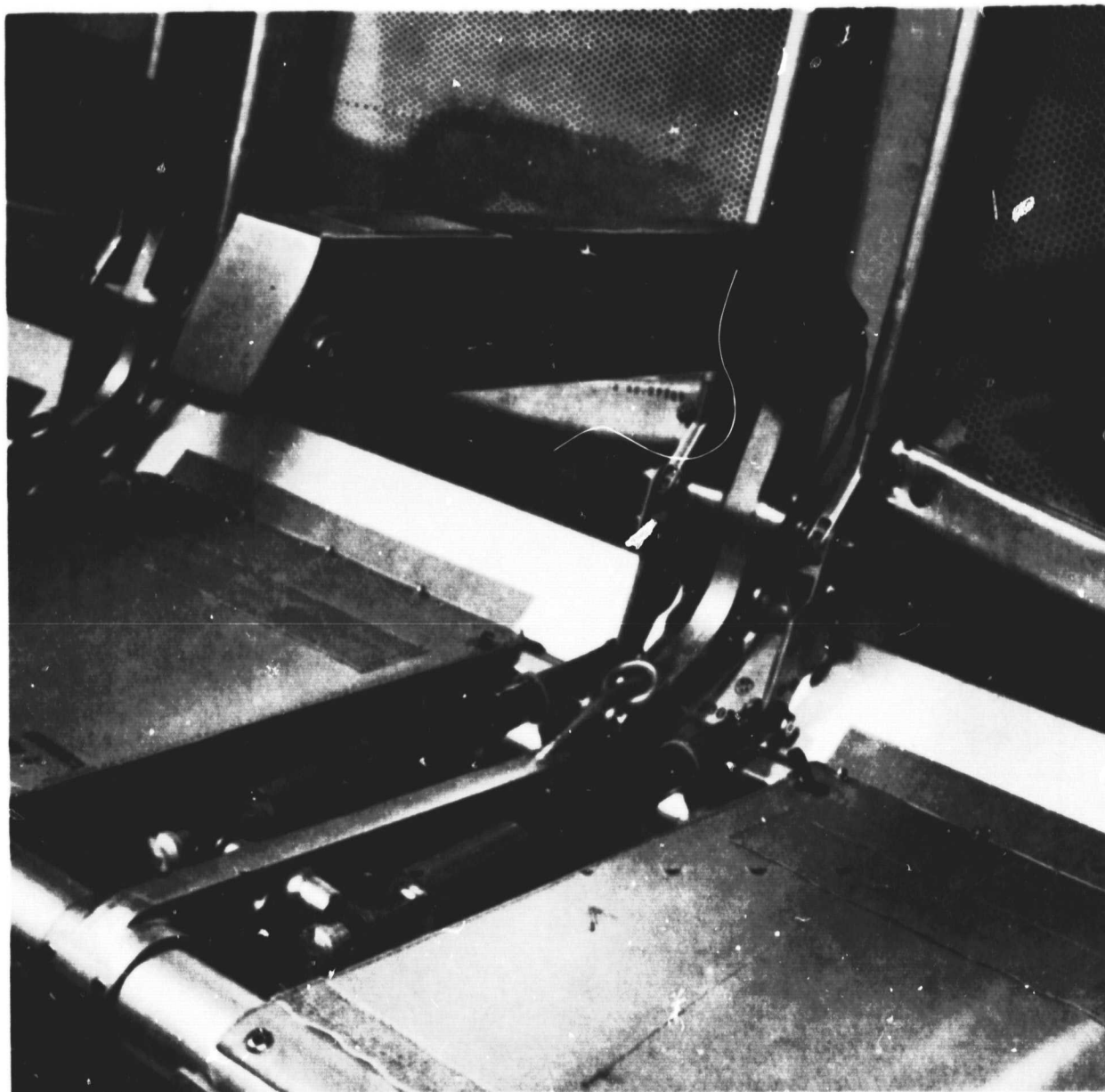
Causes for these failures may be improperly installed attachments, attachment melting, cylinder melting, and O seal distortion due to expansion of the hydraulic fluid.

The recline mechanisms frame and seat attachments are normally metal. Their physical failure would be due to an extremely hot fire in which very little of the seat would survive. The same may be said for the cylinder casing which is also metal.

Failure of the O ring would result in hydraulic fluid being lost. This fluid is not of substantial volume and its possible ignition should not prove a threat to the seat.



FIGURE 16. STRUCTURAL FRAME



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RECLINE MECHANISM

- SPRING RESTORES SEAT TO UPRIGHT POSITION SHOULD HYDRAULIC FLUID BE LOST

STRUCTURAL ATTACHMENTS

- REQUIRES INTENSE FIRE OR IMPROPER INSTALLATION FOR FAILURE

FIGURE 17. RECLINE MECHANISM

The loss of the mechanism fluid will not result in the seat reclining. The design of the mechanism is such that the spring provides for restoring the seat to its upright position regardless of the absence of hydraulic fluid.

The above discussion was in regards to a hydraulic system. A mechanical system would eliminate the O seal failure, otherwise it will have the same virtues as the hydraulic system.

An improperly installed mechanism appears the most likely of the failures to take place. In this particular instance, it would require a recline stop to regulate maximum seat back travel.

6.3 DECORATIVE SHROUDS (Figure 18)

A shroud by definition is that which covers, conceals, or protects. In regards to the aircraft seat, this means covering a sometimes less than aesthetic frame structure, concealing passenger controls, and protecting the passenger from potentially hazardous surfaces. Ruling factors in materials used for shrouds are formability and weight. If the frame structure itself could provide aesthetics, protection, and concealment, the shroud would be eliminated or reduced in mass as a potential fuel for a fire. The alternative is to use that material which best meets all needs yet will not produce a fire threat. Materials used in present shroud construction include ABS and PVC. ABS and PVC are easily formed to detailed shapes with thin, weight efficient cross sections. However, ABS and PVC have poor burn characteristics and produce large quantities of smoke when they thermally decompose. A possible alternative is the usage of a low-smoking polycarbonate or other material which will meet or exceed those values suggested in Table 1 and listed under Decorative Shroud.

6.4 ARMREST

The armrest provides comfort for the arm and acts as a divider. A study of armrests has revealed that their cushioning effect ranges from firm to very hard. Armrests on aircraft seats include polyurethane foams with a nylon skin or an extruded PVC/nylon material. Alternatives may be a self-skinning foam with LS200 neoprene burn properties or a polycarbonate extrusion. Recommended burn characteristics for armrest materials are located in Table 1.

6.5 FOOD TRAYS (Figure 19)

The food tray has three possible failure points which may appear during seat burn. These are attachments of tray structure to the seat, the tray stowage latch, and the tray materials themselves. Like the recline mechanism, the tray/seat attachments are of a metal nature and their failure would be due to an extremely intense fire. The tray stowage latch and tray materials are normally non-metallic and in the case of the tray, provide a large surface area. Failure of the stowage latch would allow the tray to lower and produce additional potential surface area to become exposed to the fire.

The food tray is an important item in that reducing its tendency to burn not only eliminates fuel to an existing fire, but due to its surface area in its stowed position, it would provide a fire barrier to seats exposed to that fire. For these reasons, careful considerations should be made in the design



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DECORATIVE SHROUD

- AREA REDUCTION OR ELIMINATION
- FIRE RETARDANT MATERIAL SUBSTITUTION

FIGURE 18. DECORATIVE SHROUD

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FOOD TRAY LATCH

- MATERIAL SUBSTITUTION
TO PREVENT FAILURE
FROM HEAT OF FIRE

FOOD TRAY

- EXPOSES LARGE
SURFACE AREA TO
FIRE WHEN LOWERED
DUE TO LATCH FAILURE

FIGURE 19. FOOD TRAYS

of the stowage latch with materials for both the latch and tray. Materials commonly found in food tray constructions includes thermoformed ABS. Due to its basically clean shape, a food tray might not require as highly formable material as ABX. Alternative materials may be metal, low smoke polycarbonate, or other materials that meet or exceed the guidelines of Table 1.

6.6 STRUCTURAL FIRE BARRIER (Figure 20)

In this section the main concern is protection to the bottom of the seat cushion from heat. Not wanting to touch on the integrity of the cushion support structural design, it is merely suggested that if a material can provide the structural physical properties required for that seat and yet protect the cushion from possible heat damage, the seat as a whole would benefit. An alternative would be a fire barrier attached to the bottom of the supportive structure. An aluminum seat bottom is offered by some seat manufacturers as an option to the cloth fabric. An alternative to the aluminum and its weight might be a fiberglass cloth with phenolic resin, while PBI and Nomex may be considered candidate materials for existing cloth fabric seat bottom designs. Suggested burn properties for a fire barrier are found in Table 1.

6.7 LITERATURE POCKET

The literature pocket's principal function is to provide a convenient location for the Emergency Information Card, the airline magazine, and the air sickness containers. Unfortunately, they are also a convenient compartment for stowage of a passenger's flammable carry-on paper products including facial tissues, newsprint, and worst of all, cigarette by-products. All of these items are of concern because they will provide fuel to an existing fire as well as produce a fire themselves.

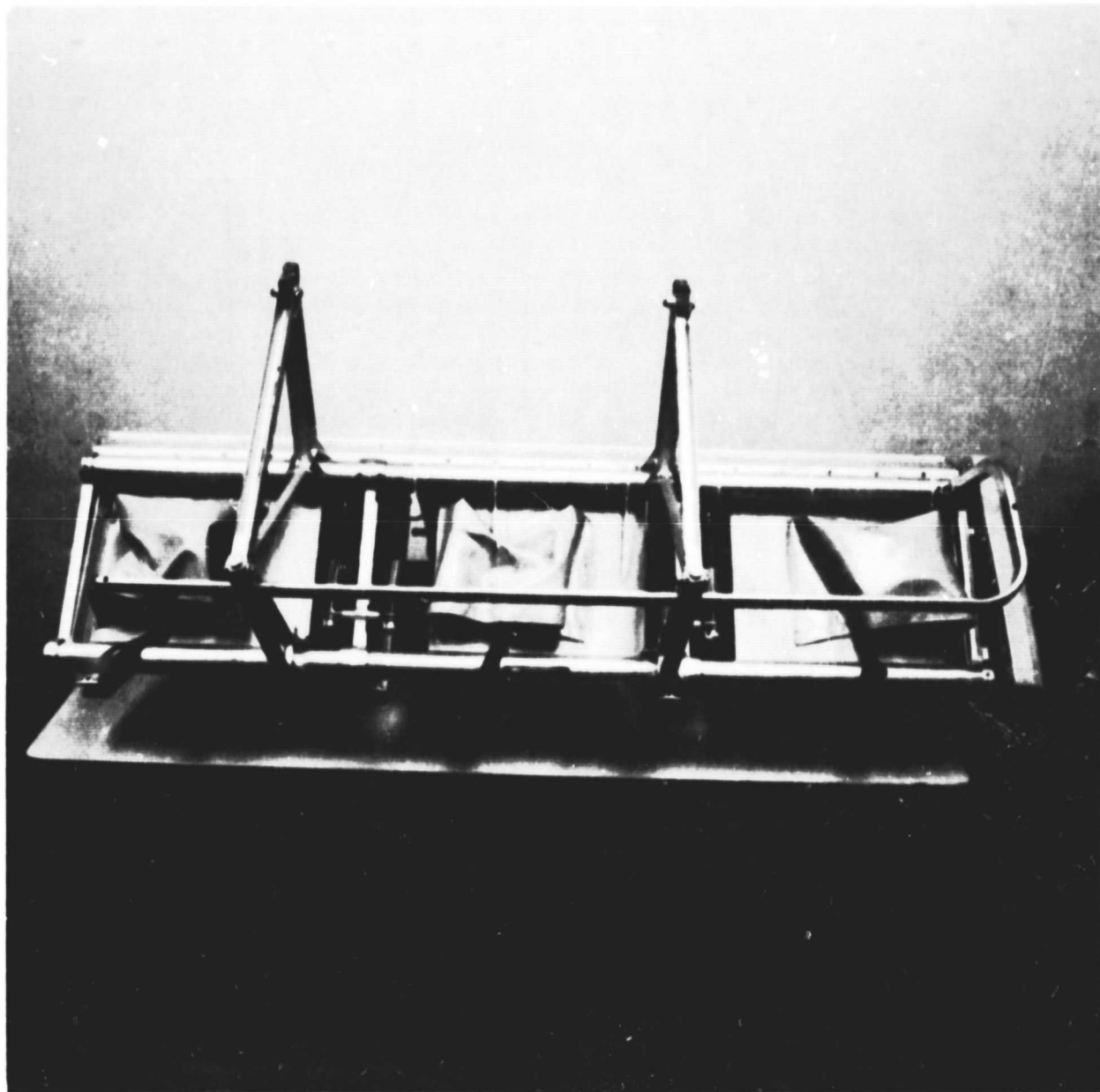
Literature pocket design considerations might involve providing visibility of a potential fire hazard as well as visibility of a smoldering fire. In conjunction with the design, materials could be chosen which would contain a fire within the pocket or protect the pocket's contents from an existing fire. Fire containment/resistance might include a fire resistant pocket lining material, fire resistant decorative upholstery materials, and an air-tight seal for the pocket opening.

6.8 SEAT CUSHIONS

Seat cushions provide a large volume source of fuel for starting or supplying a fire. A basic passenger seat consists of a cushioning layer, slip cover, and a decorative upholstery material. The cushioning layer provides the majority of the seat cushion volume and depending on their usage may contain a flotation layer as well as a cushioning layer.

Studies have been and are still being made on the best way to protect or replace the cushioning layer. These include fire resistant upholstery materials, fire blocking layers, and total replacement of the cushioning layer with foams more resistant to thermal decomposition. At the time of this writing, fire blocking materials available were a higher density than the materials they were to replace, causing significant weight impacts on the aircraft. It

must be determined to what degree a fire-hardened cushion must retain physical properties that now exist. It is beyond the scope of this guide to determine optimum fire blocking layers thicknesses or material properties needed to meet passenger comforts.



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SEAT BOTTOM FIRE BARRIER

- FIRE BARRIER ATTACHED TO SUPPORTIVE STRUCTURE
- MATERIAL SUBSTITUTION TO PROVIDE STRUCTURAL CUSHION SUPPORT AND FIRE PROTECTION TO CUSHION

FIGURE 20. STRUCTURAL FIRE BARRIER

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SECTION 7

RECOMMENDATIONS

This completes the laboratory screening and multi-layer testing of materials for the NASA Fire Resistant Seat Program in preparation for full scale cushion burn testing. Laboratory tests have shown positive results when fire blocking layers were used. However, their optimum application in cushion design was beyond the scope of this program.

It is therefore recommended that additional programs be funded which will continue the study of fire blocking materials and to determine their optimum usage.

SECTION 8

PASSENGER SEAT ASSEMBLY

A 3-abreast "tourist class" passenger seat assembly was constructed using improved fire resistant seat materials. Materials used in this seat are described in Table 9 as Test No. 6. The bottom cushion consisted of a 1/2 inch LS200 neoprene layer on the top and front sides of a polyimide foam block. The LS200/Polyimide cushion was completely covered on all sides by a layer of Nomex III. 20787 Kermel/Wool blend upholstery material was attached per Fairchild Burns manufacturing practices. The back cushion and headrest were identical to the bottom cushion with the exception of a 1/4 inch layer of LS200 neoprene on the front (passenger) side instead of a 1/2 inch layer. The cushions were fitted to a Fairchild Burns Airest 2000 seat assembly.

This design is considered the most advanced in relation to fire-resistant seat cushion materials. This design is not presently used in aircraft production seats and employs materials with fire retardent properties. This passenger seat assembly was shipped to Ames Research Center, Moffett Field, California 94035, Receiving Department 221-5, M/F NAS 2-9337.

APPENDIX A
MATERIAL TEST PROCEDURES

MATERIAL TEST PROCEDURES

SCREENING TESTS

All materials were first screened to current FAA burn requirements. Screening tests consisted of a series of selected small scale laboratory tests. The combination of these screening tests represented a significantly higher fire resistance performance standard than laboratory test standards currently imposed on aircraft seat materials.

The modified burn test was the only nonstandard test that was conducted. The modification took into account that the standard burn test permits melting material to be removed from the direct flame by the very mechanism of melting and in affect reducing exposure time to the flame for those materials.

SCREENING TEST METHODS

| FABRIC | | FOAM | |
|------------|---------------------------|-----------|---------------------------|
| PROPERTY | TEST METHOD | PROPERTY | TEST METHOD |
| Screening: | | | |
| Weight | *Method 5041 | Density | ASTM 1564 Suffix W |
| Burn | **FAR 25.853(b) | Burn | **FAR 25.853(b) |
| | **FAR 25.853(a) | | **FAR 25.853(b) Mod. |
| NBS Smoke | ***Tech Note 708 | NBS Smoke | ***Tech Note 708 |
| | | Ignition | ASTM D2859 |
| | | LOI | ASTM D2863-70 |
| | | TGA | At 20°C per minute in air |
| LOI | ASTM D2863-70 | | |
| TGA | At 20°C per minute in air | | |

*Federal Test Method Standard No. 191, Textile Test Methods

**Federal Aviation Regulations Part 25 Airworthiness Standards: Transport Category Airplanes

***NBS Technical Note No. 708; Test Method for Measuring the Smoke Generation Characteristics of Solid Materials

RELATIVE TOXICITY TESTS

Swiss-Webster strain albino mice weighing approximately 25 grams were exposed to pyrolysis/combustion products generated within a 5.3 liter volume rectangular glass chamber sealed at the top with a plexiglass lid. An exercise wheel and drive mechanism, electrical power leads for the microcombustion tube used for pyrolysis/combustion of the sample, and a radiation shield were mounted on the lid.

With the subject placed inside the exercise wheel and a 0.5-gram sample loaded into the microcombustion tube (connected to a power lead), aluminum foil radiation shield in place, assembly integral with the lid was inserted in the chamber and clamped in sealed position. A magnetically-driven fan stirrer was placed in the chamber to provide rapid mixing of the pyrolysis/combustion products evolved from the test specimen during a run.

Final preparation for conducting a test consisted of connecting a variable speed electric motor to drive the exercise wheel and the Variac transformer controlled power leads to the pyrolysis/combustion tube feed through leads on the lid. The test parameters used in these tests were:

Exercise wheel rotation speed — 6 RPM

Input power — 20 VAC, 5.3 amperes

Sample heating rate — 300°C/minute

Heating period — 200 seconds

Biological endpoints — time to incapacitation, T_i
time to death, T_d

Total test time (per run) — 30 minutes

THERMOGRAVIMETRIC ANALYSIS

The candidate materials were tested for weight loss by standard procedures using a DuPont Instrument Company Thermal Analyzer. Approximately 5 to 15 mg samples were introduced into the sample cup and heated at a rate of 20°C per minute in a low flow of dry air (75 ml/min). Rates of weight loss versus temperature (time) were recorded by potentiometric recorder until no further weight loss was detected (usually in 30 to 35 minutes).

HEAT AND SMOKE RELEASE RATE AND THERMAL PENETRATION TESTS

The candidate multilayer seat cushion specimens were tested in the Ohio State University version of the heat release rate calorimeter (HRR). This calorimeter was used to evaluate the heat and smoke released from 25 x 25 cm multilayer specimens laid up in the sample holder as shown in Figure A-1 when exposed to a radiant flux of 3.5 w/cm². Quantitative measures of heat released in terms of kilowatt (kw) or BTU/minute were calculated per square meter (m²) of original surface areas exposed as a function of time.

The Douglas (modified) HRR chamber and auxiliary pen recorder and gas monitoring instrumentation is employed to evaluate the fire response of nonmetallic materials. The principal value of testing the seat materials in the HRR calorimeter was to provide an insight into the dynamic response of each material in a fire environment, and the potential contribution of each material in the cushion to the propagation of fire. These characteristics are applicable to the identification and selection of the best materials for seat construction in each use category as discussed in the report.

A special modified, lightweight, stainless steel sample holder and refractory backing board of low thermal capacitance was used for all tests to reduce heat absorption by the holder immediately following injection of the mounted sample into the HRR chamber. As indicated in Figure A-1 up to 3 chromel alumel thermocouples were included in the multilayer test specimens to measure the thermal penetration rates of heat into the layup at three locations (two on baseline specimens). Samples were stored in a laboratory atmosphere varying from 38-45 percent relative humidity.

The electrically powered Glowbar^R radiant panel heating source was adjusted to the required thermal flux using a Hycal Radiometer-Calorimeter and allowed to equilibrate to a constant level with air flowing through the chamber. In most tests baseline recorded temperature variations (noise) differentially recorded between the air input temperature and the exit stack of the HRR were observed to hold within ± 0.5 division of chart (equivalent to approximately 1 Kw/m² heat release).

The recorded curves of heat (temperature) were read out and calculated against calibrations obtained at the same airflow setting as the test materials using natural gas of known heat content.

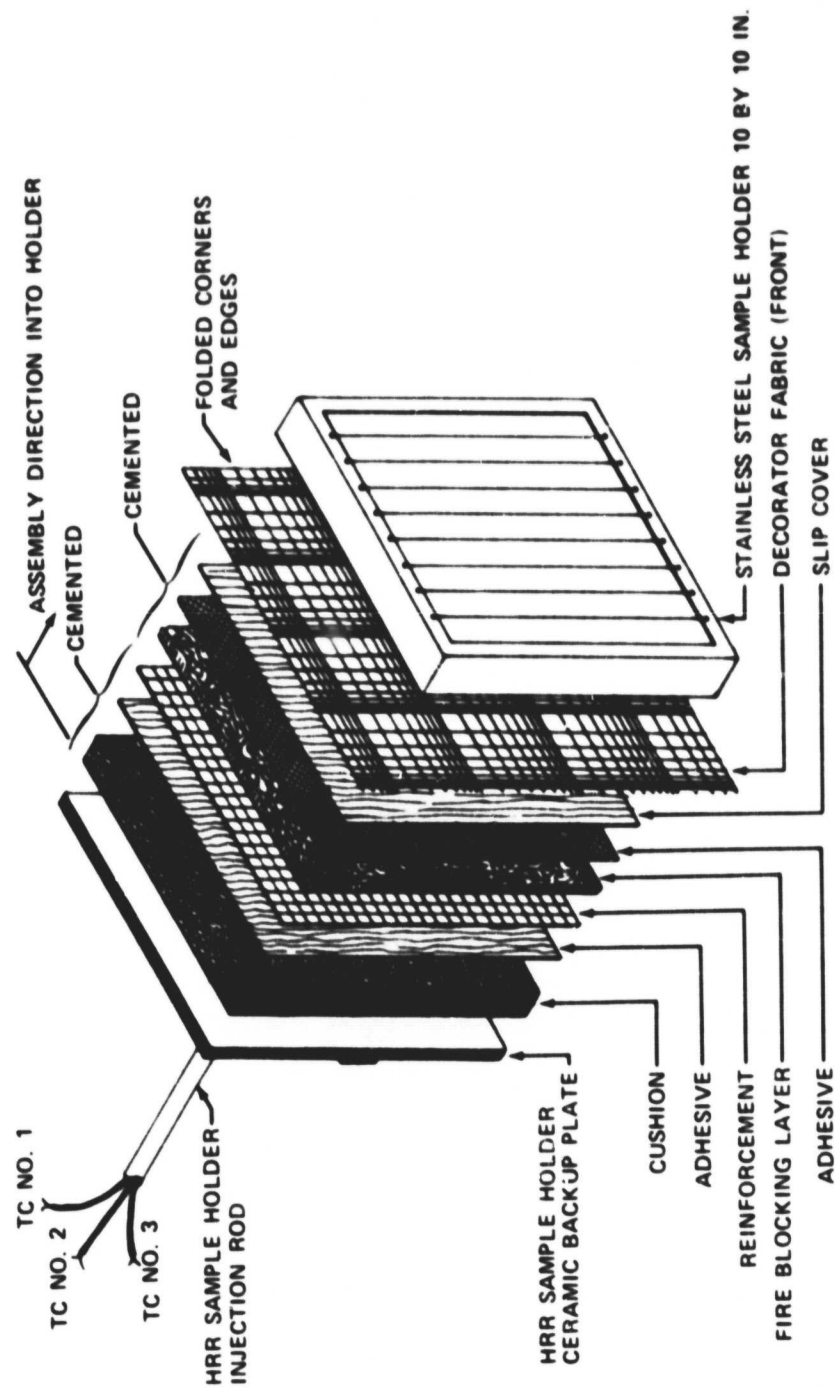


FIGURE A-1. TYPICAL MULTIPLE LAYER TEST SPECIMEN

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APPENDIX B
MATERIAL TEST RESULTS

TABLE B-1
LIST OF MATERIALS SCREENED

| MATERIAL NUMBER | PRODUCT NUMBER | MATERIAL DESCRIPTION | TRADE NAME | SUPPLIER |
|-----------------|----------------|---|-------------|--|
| 101 | 20787 | Kermel/Wool Blend Decorative Fabric | Kermel/Wood | H. Lelievre Paris, France |
| 104 | ST4227-112 | 90% Wool/10% Nylon Blend Sun Eclipse Blue, Decorative Fabric | | Collins & Aikman Charlotte, NC & Albemarle, SC |
| 117 | 3177 | 100% Wool, Sedellia Blue Decorative Fabric | | Collins & Aikman Charlotte, NC |
| 216 | 400-11 | Durette Needle Punch Felt (Chlorinated Aramid) 10.4 oz/yd ² | Durette | Fire Safe Products St. Louis, MO |
| 221 | S/470 | Nomex Duck Fabric (Natural) 7.5 oz/yd ² | Nomex III | Southern Mills Senoia, Georgia |
| 228 | 44/40 Cnt | Cotton Muslin 44/40 Cnt | | Hanes Converting P. O. Box 457 Conover, NC 28613 |
| 229 | 3/PS | Vonar 3/PS Interliner with Polyester Scrim | Vonar | Allen Industries, Inc. Richmond, VA |
| 300 | FG215 | Glass Fiber Clock Cushion (Edge Grain) | | Expanded Rubber & Plastics Gardena, CA |
| 317 | LS200 | Neoprene Foam 8 #/Ft ³ | Toyad | Toyad Corp. Latrobe, PA 15650 |
| 322 | S2850 | Urethane Foam (Baseline) | | Reeves Brothers Charlotte, NC 28213 |

TABLE B-1 (CONTINUED)
LIST OF MATERIALS SCREENED

| MATERIAL NUMBER | PRODUCT NUMBER | MATERIAL DESCRIPTION | TRADE NAME | SUPPLIER |
|-----------------|---------------------------------|---|------------|--|
| 323 | 1720-1 1.5 #/Ft ³ | Polyimide Foam, Flexible 1.5 p.c.f. | | Solar Turbine & International San Diego, CA |
| 324 | 2043 FA 2 #/Ft ³ | Urethane Foam | | North Carolina Foam Ind. Mount Airy, NC 27030 |
| 412 | M | Closed Cell PVC Foam | Ensolute | Uniroyal Mishawaka, IN 46544 |
| 413 | ALS | Closed Cell PVC Foam | Ensolute | Uniroyal Mishawaka, IN 46544 |
| 414 | S32.50 | Closed Cell PVC Foam 3 lbs/Ft ³ | Airex | Lonza, Inc. Fair Lawn, NJ 07410 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

TABLE B-2
ANIMAL TOXICITY TEST RESULTS

| MATERIAL NO. & NAME | MATERIAL WEIGHT GRAMS | ANIMAL WEIGHT GRAMS | OBSERVED | | NORMALIZE DATA PER GM MATL 25 CM MOUSE | | APPARENT MATERIAL PYROLYZED MG | APPARENT PYROLYZED MATL. CONC. IN CHAMBER MG/l | NOTES |
|---------------------------|-----------------------------|---------------------------|------------|------------|---|--------------------------|---|--|-------------------------------|
| | | | T1 MIN. | Td MIN. | T1 | Td | | | |
| | | | | | | | | | |
| Ensolite M (412) | 2/1 | 0.2481 | 27.7 | 5.65 | - | 1.27 | 143 | 27 | Char Yield = 41% |
| | 2/2 | 0.2537 | 26.4 | 4.00 | 9.00 | .96 | 152 | 29 | Yc = 41% |
| | 2/3 | 0.2576 | 24.2 | 4.43 | 9.53 | 1.18 | 145 | 27 | Yc = 44% |
| | 2/4 | 0.2768 | 24.2 | 4.80 | 34.58 | 1.37 | 164 | 31 | Yc = 41% |
| AV | | | | | | $\bar{X} = 1.2 \pm 0.17$ | | | Max. Chamber Temp. 87-90°F |
| Ensolite ALS (413) | 1/1 | 0.9802 | 26.6 | 1.55 | 4.0 | 1.43 | 598 | 113 | Yc = 39% |
| | 1/2 | 0.2790 | 27.0 | 4.07 | 30.5 | 1.05 | 159 | 28 | Yc = 43% |
| | 1/3 | 0.2752 | 23.8 | 4.00 | >33.3 | 1.16 | 154 | 29 | Yc = 44% |
| | 1/4 | 0.2742 | 26.2 | 4.58 | 23.75 | 1.20 | 153 | 29 | Yc = 44% |
| | | | | | | $\bar{X} = 1.2 \pm 0.16$ | | | Max. Chamber Temp. 87-90°F |
| Airex Foam (414) | 3/4 | 0.5292 | 25.3 | 5.23 | 7.42 | 2.74 | 473 | 89 | Yc = 11% |
| | 3/5 | 0.5395 | 25.1 | 4.17 | 4.75 | 2.24 | 505 | 95 | Yc = 6.4% |
| | 3/6 | 0.5051 | 25.0 | 5.67 | 11.25 | 2.86 | 458 | 86 | Yc = 9.4% |
| | | | | | | $\bar{X} = 2.6 \pm 0.33$ | | | Max. Chamber Temp. 88-92°F |
| Polyimide Foam (323) | 4/1 | 0.5254 | 27.8 | 3 | 4.47 | 1.42 | 42 | 42 | Yc = 57.8% |
| | 4/2 | 0.2455 | 31.1 | 4.92 | 11.63 | 0.97 | 10.6 | 19 | Yc = 59% |
| | 4/3 | 0.2656 | 29.7 | 4.2 | 11.25 | 0.94 | 110.6 | 21 | Yc = 58.4% |
| | | | | | | $\bar{X} = 2.6 \pm 0.33$ | | | Max. Chamber Temp. 84-87°F |
| Vonar III/PS (229) | 5/1 | 0.5205 | 26.6 | No | No | No | 267.8 | 50.5 | Yc = 48.6% |
| | 5/2 | 1.4991 | 28.8 | No | No | No | 745.4 | 140.6 | Yc = 50.3% |
| | | | | | | | | | Max. Chamber Temp. 90°F |
| Cotton Muslin (228) | 6/1 | 0.5192 | 29.0 | 6.17 | 13.4 | 2.76 | 348 | 55.8 | Yc = 33% |
| | 6/2 | 0.5245 | 27.3 | 5.53 | 14.95 | 2.66 | 351 | 66.3 | Yc = 33% |
| | 6/3 | 0.5276 | 32.4 | 6.25 | 17.70 | 2.55 | 353 | 67 | Yc = 33% |
| | | | | | | $\bar{X} = 2.7 \pm 0.10$ | | | Max. Chamber Temp. 85-88°F |

TABLE B-2 (CONTINUED)
ANIMAL TOXICITY TEST RESULTS

| MATERIAL NO. & NAME | MATERIAL WEIGHT GRAMS | ANIMAL WEIGHT GRAMS | OBSERVED | | NORMALIZE DATA PER GM MATL 25 GM MOUSE | | APPARENT MATERIAL PYROLYZED MG | APPARENT PYROLYZED MATL. CONC. IN CHAMBER MG/l. | NOTES |
|--|-----------------------------|---------------------------|------------|------------|---|-----------|---|---|---|
| | | | Ti MIN. | Td MIN. | Ti | Td | | | |
| Nomex 3 (221) | 7/1 | 0.5252 | 3.33 | 6.13 | 1.55 | 2.85 | 249.6 | 47.1 | Yc = 53% |
| | 7/2 | 0.3137 | 4.67 | 16.5 | 1.25 | 4.42 | 155.1 | 29.3 | Yc = 51% |
| | 7/3 | 0.3084 | 3.82 | 6 | 1.07 | 1.68 | 150.5 | 28.4 | Yc = 51% |
| | | | | | $\bar{X} = 1.29 \pm 0.24$ | | | | Max. Chamber Temp. 80-88°F |
| Sedallia Blue (117) | 8/1 | 0.5218 | 2.18 | 3.43 | 0.98 | 1.53 | 365.6 | 72.75 | Yc = 26% |
| | 8/2 | 0.1549 | 4.53 | 10.83 | 0.63 | 1.51 | 123.8 | 23.36 | Yc = 20% |
| | 8/3 | 0.1559 | 3.57 | 9.67 | 0.48 | 1.29 | 113.2 | 21.36 | Yc = 27% |
| | | | | | 0.7 ± 0.25 | | | | Max. Chamber Temp. 82-86°F |
| 9-1 2043 FA Baseline PU Foam (324) | | 224.5 | 375sec | 420sec | 1.799 min | 2.015 min | 14.9715 14.5615 0.4100 CY 16.21% | 77.36 | Temp. 76°F - Very dense smoke, hardly see the mice at 110 sec smoke kept coming out at 200 sec Max. Temp. 86°F |
| | | | | | | | | | |
| | | | | | | | | | |
| 9-2 2043 FA Baseline PU Foam (324) | | 216.5 | 283sec | 440sec | 1.620 min | 2.517 min | 14.9818 14.5646 0.4172 CY 11.93% | 78.71 | Start Temp. 80°F Max. Temp. 87°F |
| | | | | | | | | | |
| | | | | | | | | | |
| 9-3 2043 FA Baseline PU Foam (324) | | 219.5 | 458sec | 688sec | 2.494 | 3.746 | 14.9562 14.5700 0.3862 CY 21.18% | 72.87 | Start Temp. 76°F Max. Temp. 88°F |
| | | | | | | | | | |
| | | | | | | | | | |

RUN# 0200

DAC#317 LS 200

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

46 1.5

94 3

129 5

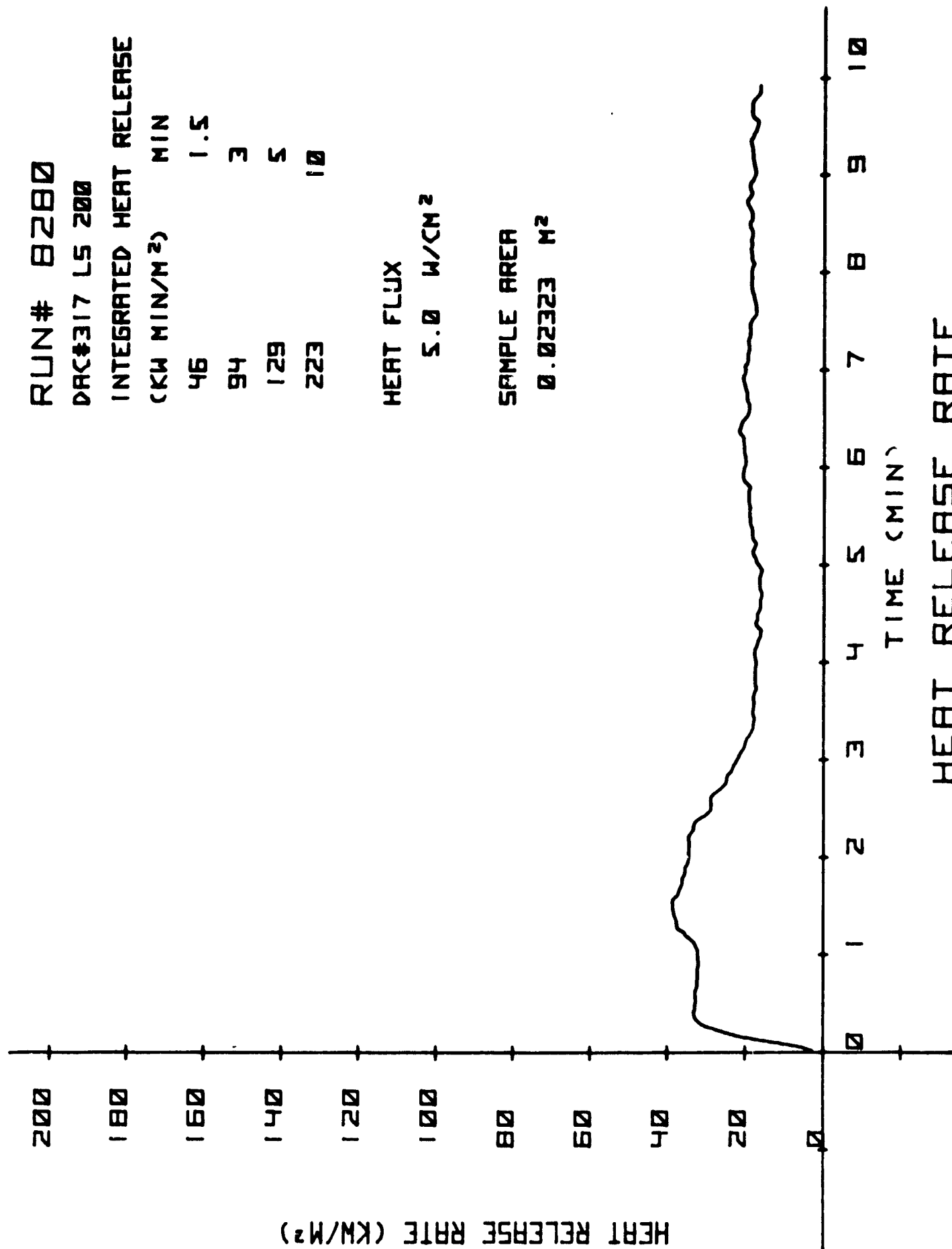
223 10

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²

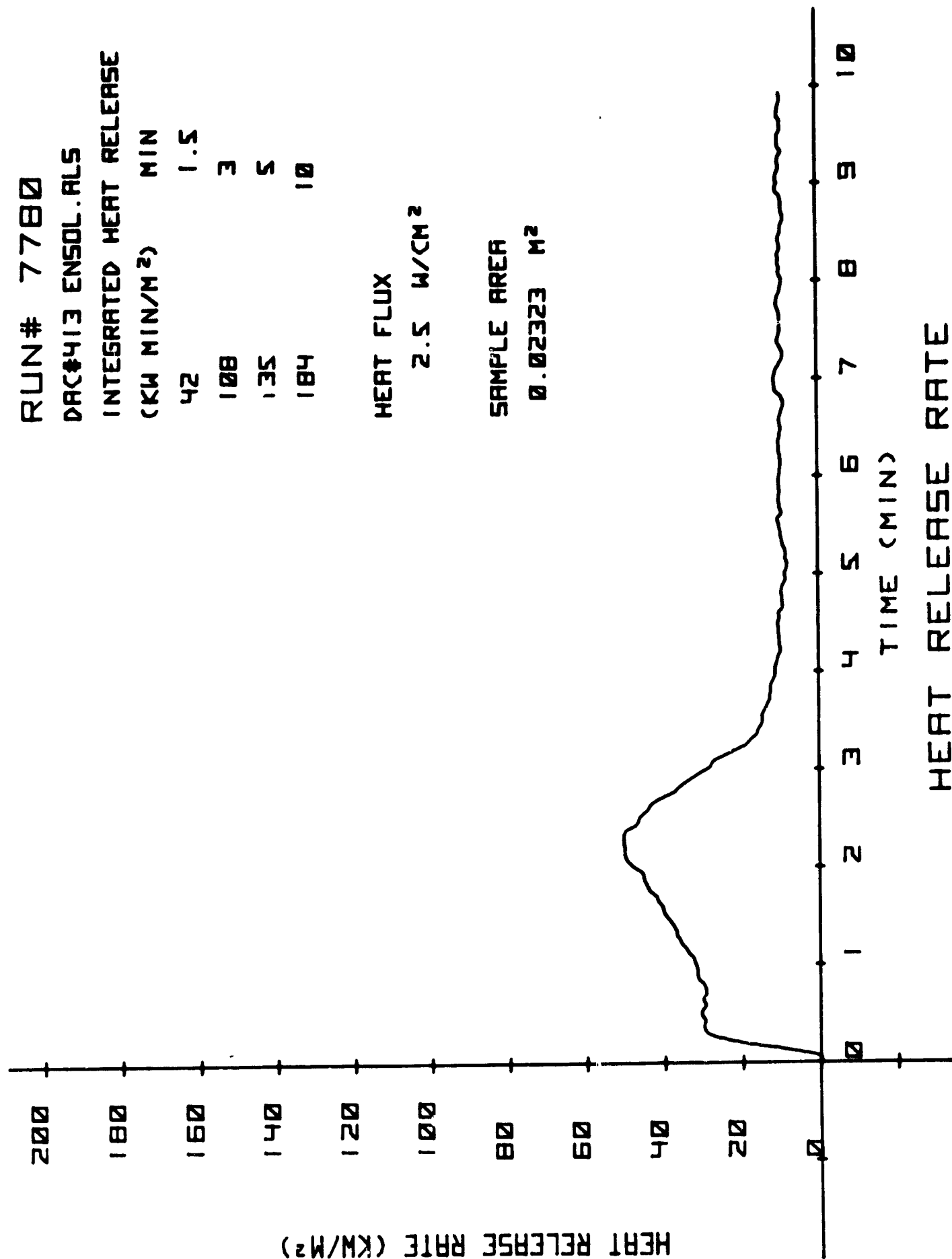


HEAT RELEASE RATE

RUN# 7780
 DAC#413 ENSOL.ALS
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 42 1.5
 108 3
 135 5
 184 10

HEAT FLUX
 2.5 W/CM²

SAMPLE AREA
 0.02323 M²



RUN# 7580

DAC#413 ENSOL. ALS

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

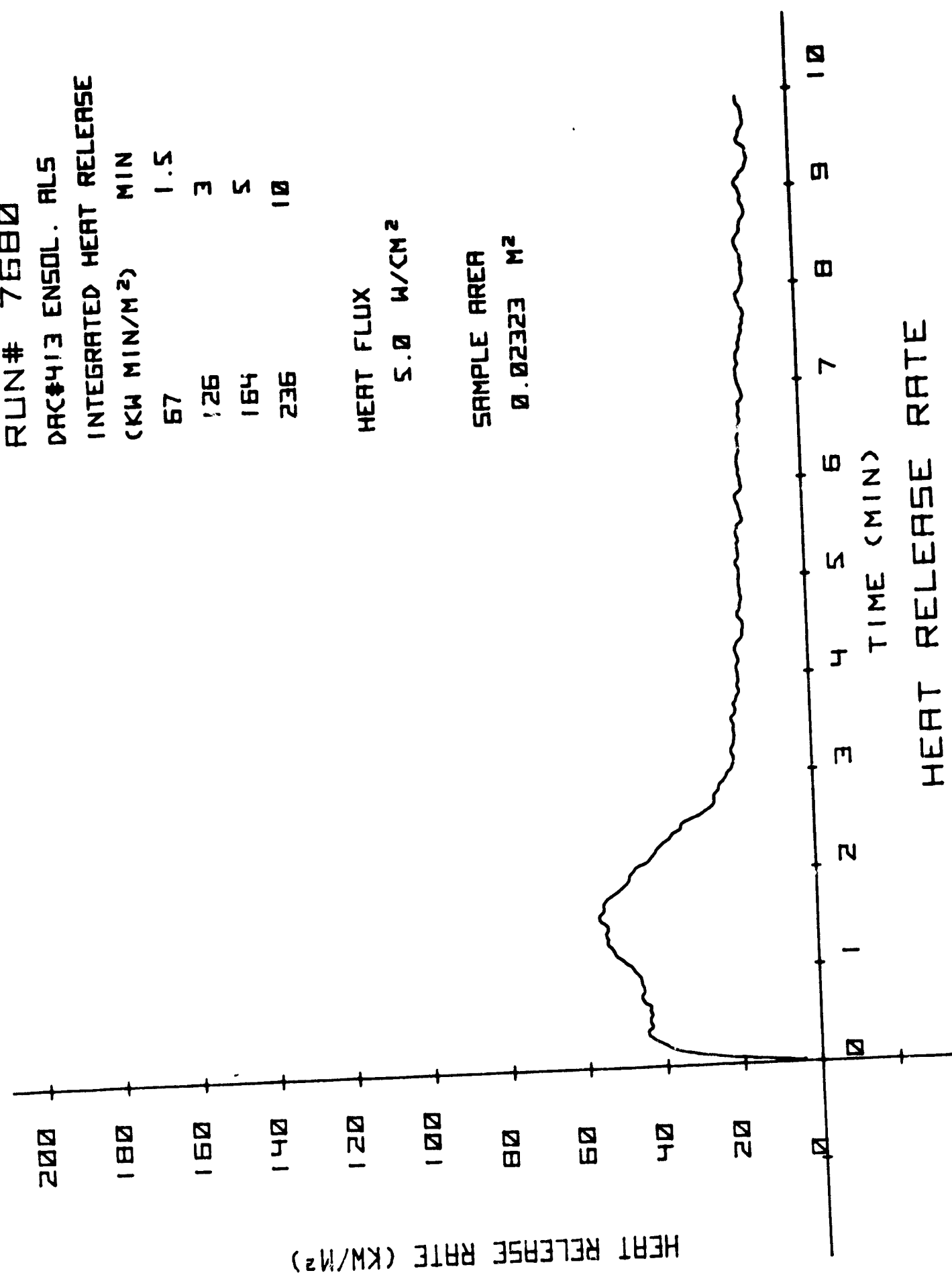
| | |
|-----|-----|
| 67 | 1.5 |
| 126 | 3 |
| 164 | 5 |
| 236 | 10 |

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 7580

DAC#228 COT. MUSLIN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

7 1.5

11 3

21 5

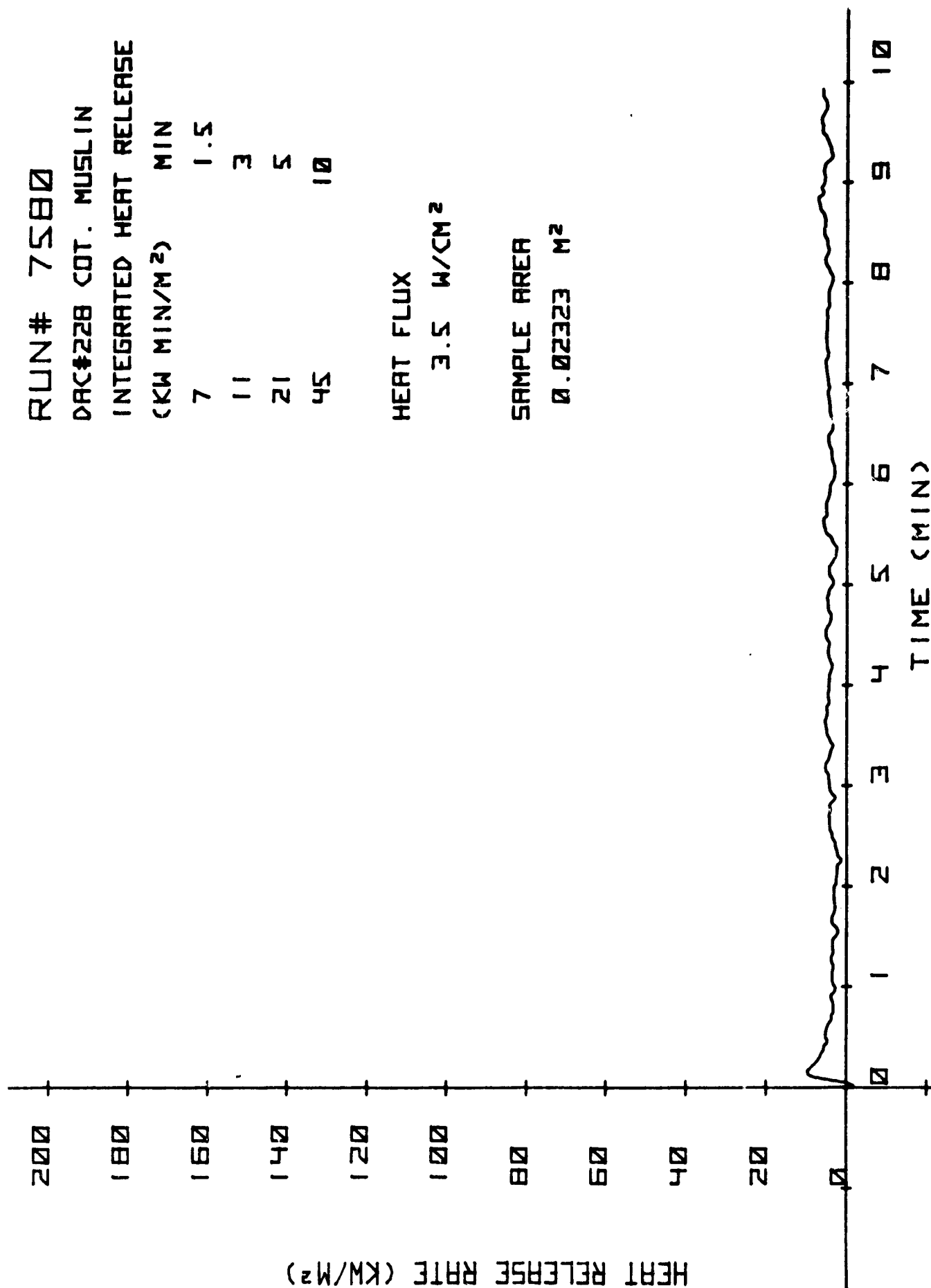
45 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²

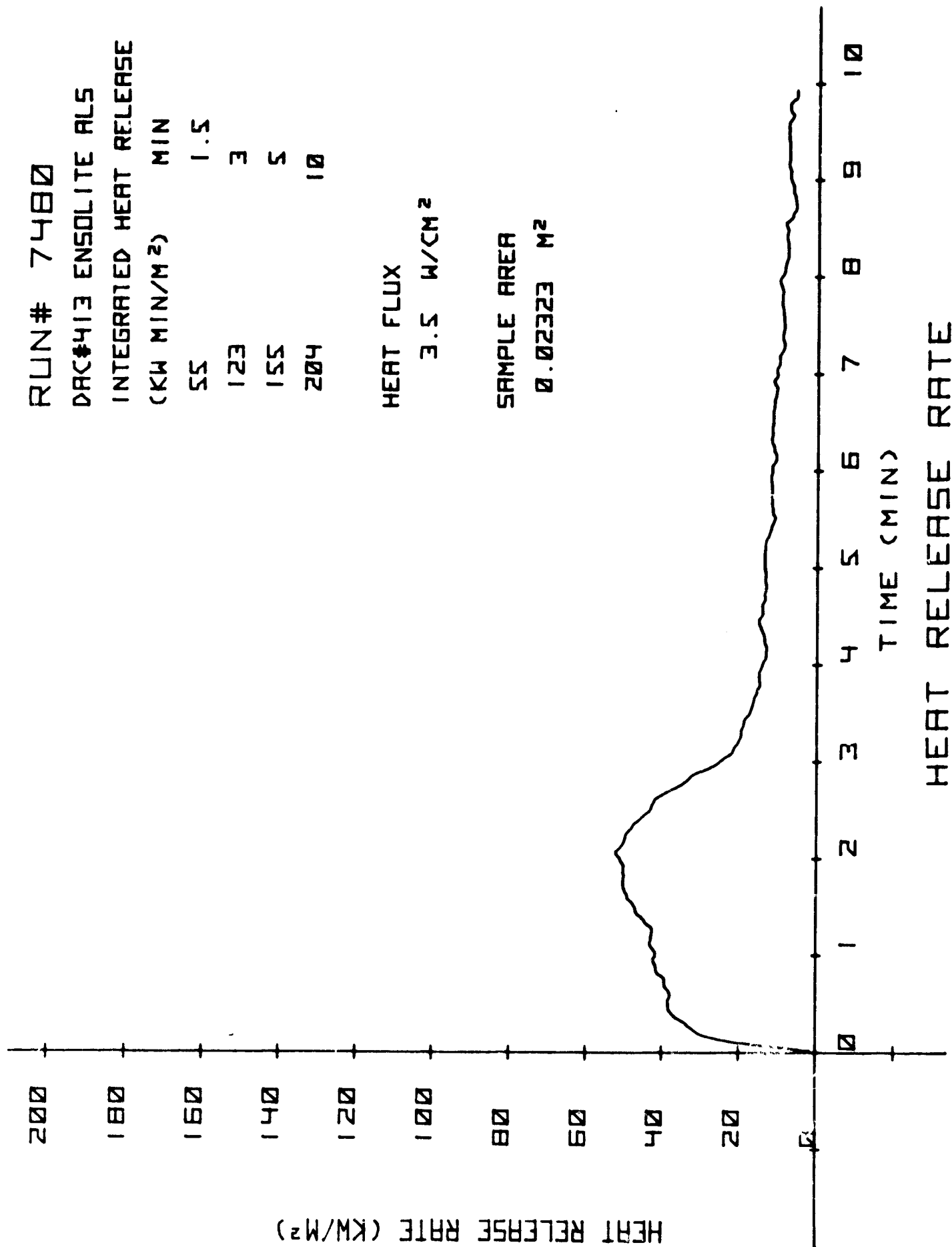


HEAT RELEASE RATE

RUN# 7480
 DAC#413 ENSOLITE ALS
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 55 1.5
 123 3
 155 5
 204 10

HEAT FLUX
 3.5 W/CM²

SAMPLE AREA
 0.02323 M²



HEAT RELEASE RATE

RUN# 7380

DAC#412 ENSOL. M

INTEGRATED HEAT RELEASE

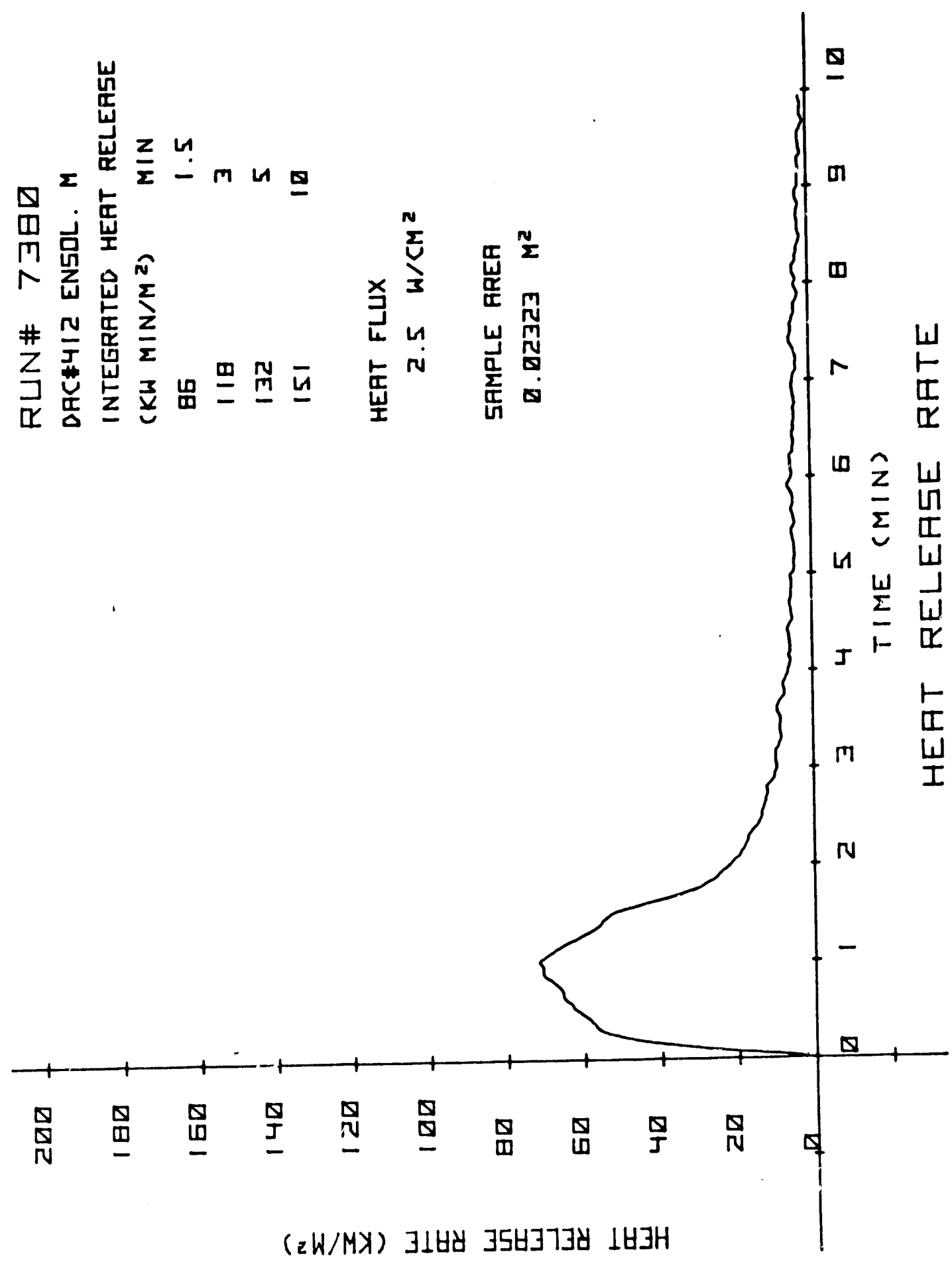
| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 86 | 1.5 |
| 118 | 3 |
| 132 | 5 |
| 151 | 10 |

HEAT FLUX

2.5 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 7280

DAC#317 LS 200

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-3 1.5

-1 3

5 5

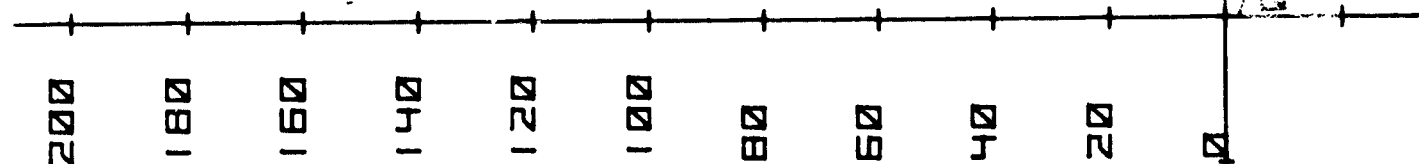
50 10

HEAT FLUX

2.5 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE (KW/M²)

TIME (MIN)

HEAT RELEASE RATE

RUN# 7180

DAC#317 LS200

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

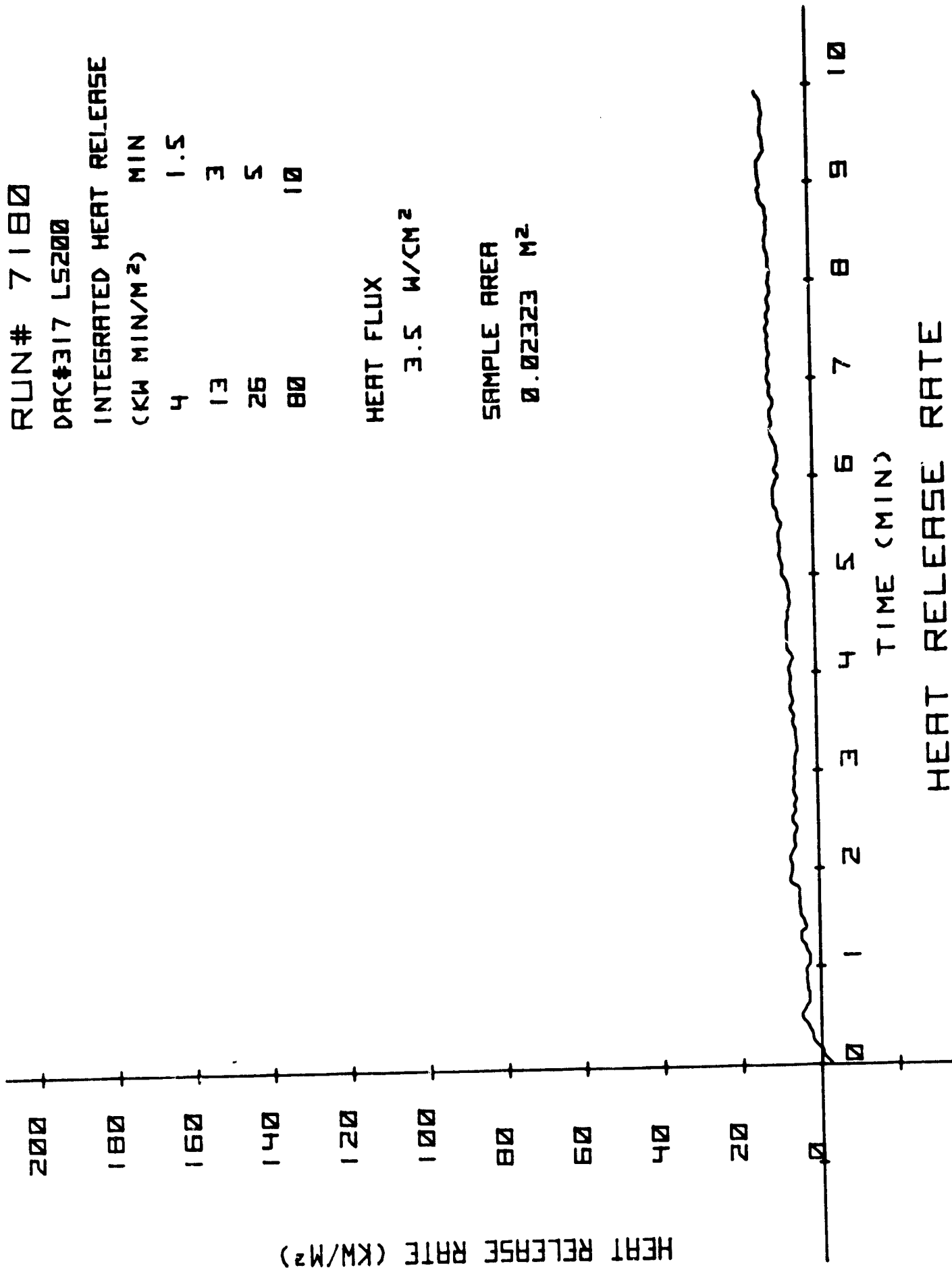
| | |
|----|-----|
| 4 | 1.5 |
| 13 | 3 |
| 26 | 5 |
| 80 | 10 |

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 7080

DAC#412 ENSOLITE M

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

101 1.5

136 3

163 5

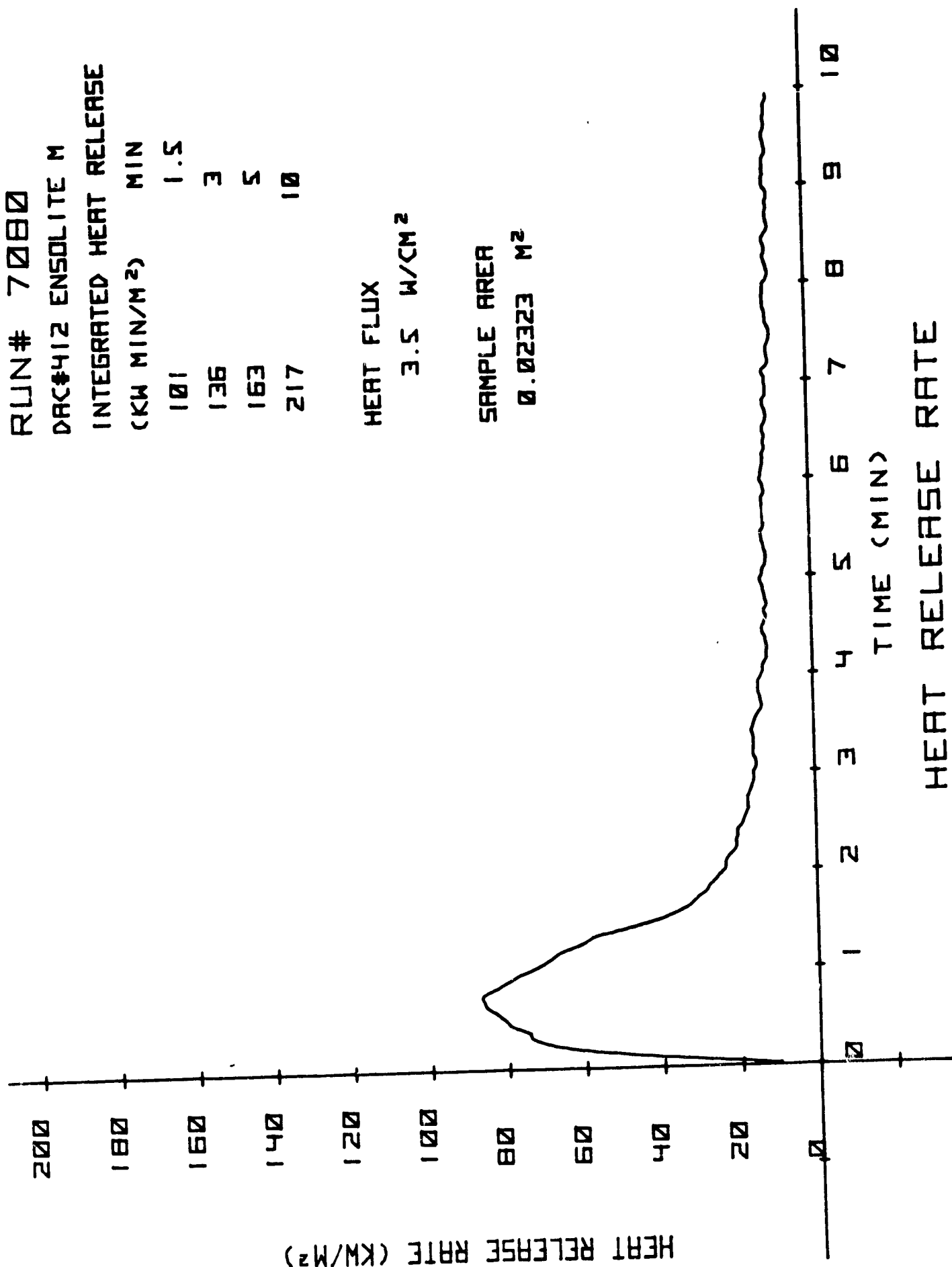
217 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE

RUN# 6980

DRC#322 P U FORM

INTEGRATED HEAT RELEASE

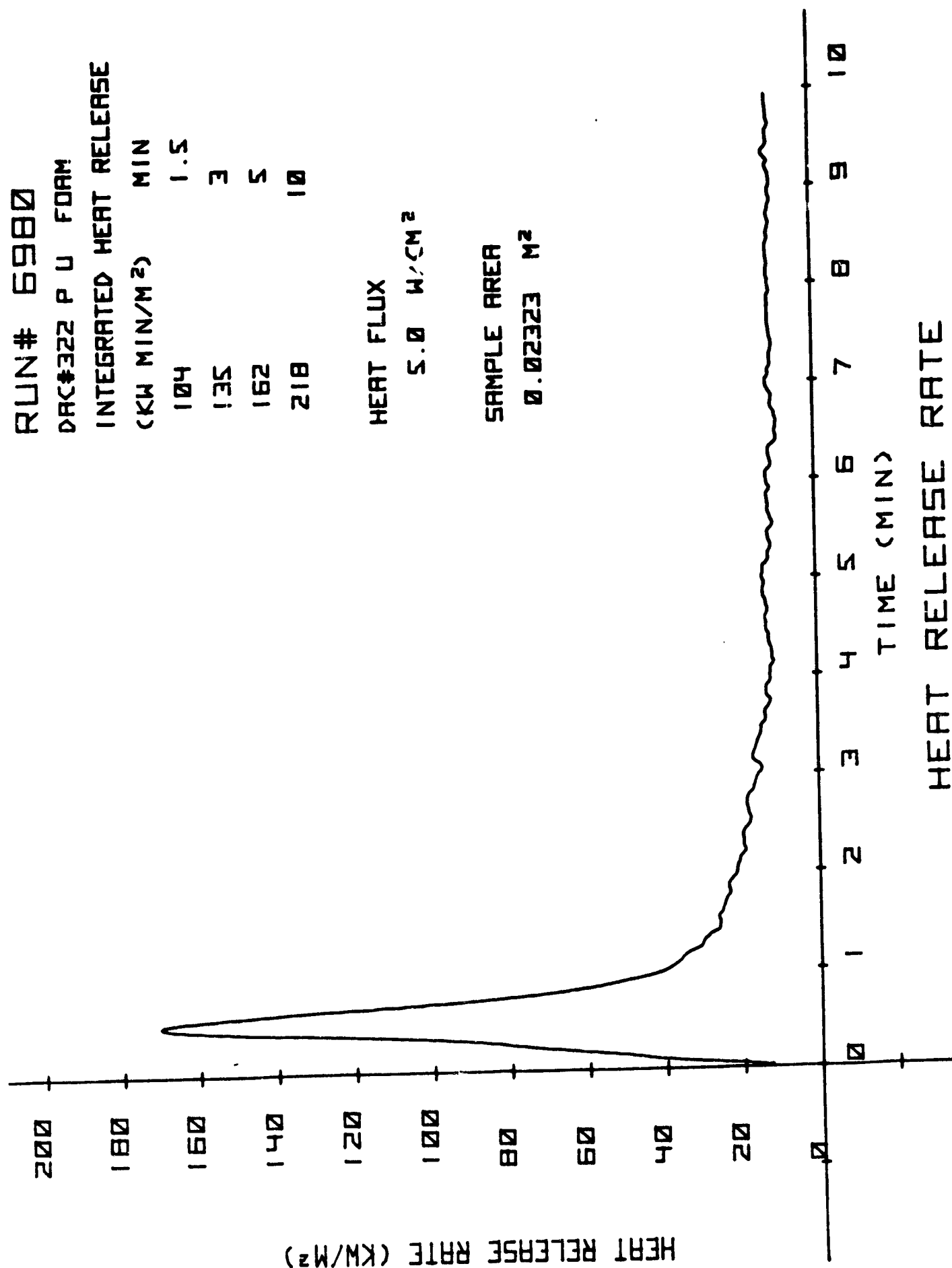
| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 104 | 1.5 |
| 135 | 3 |
| 162 | 5 |
| 218 | 10 |

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²

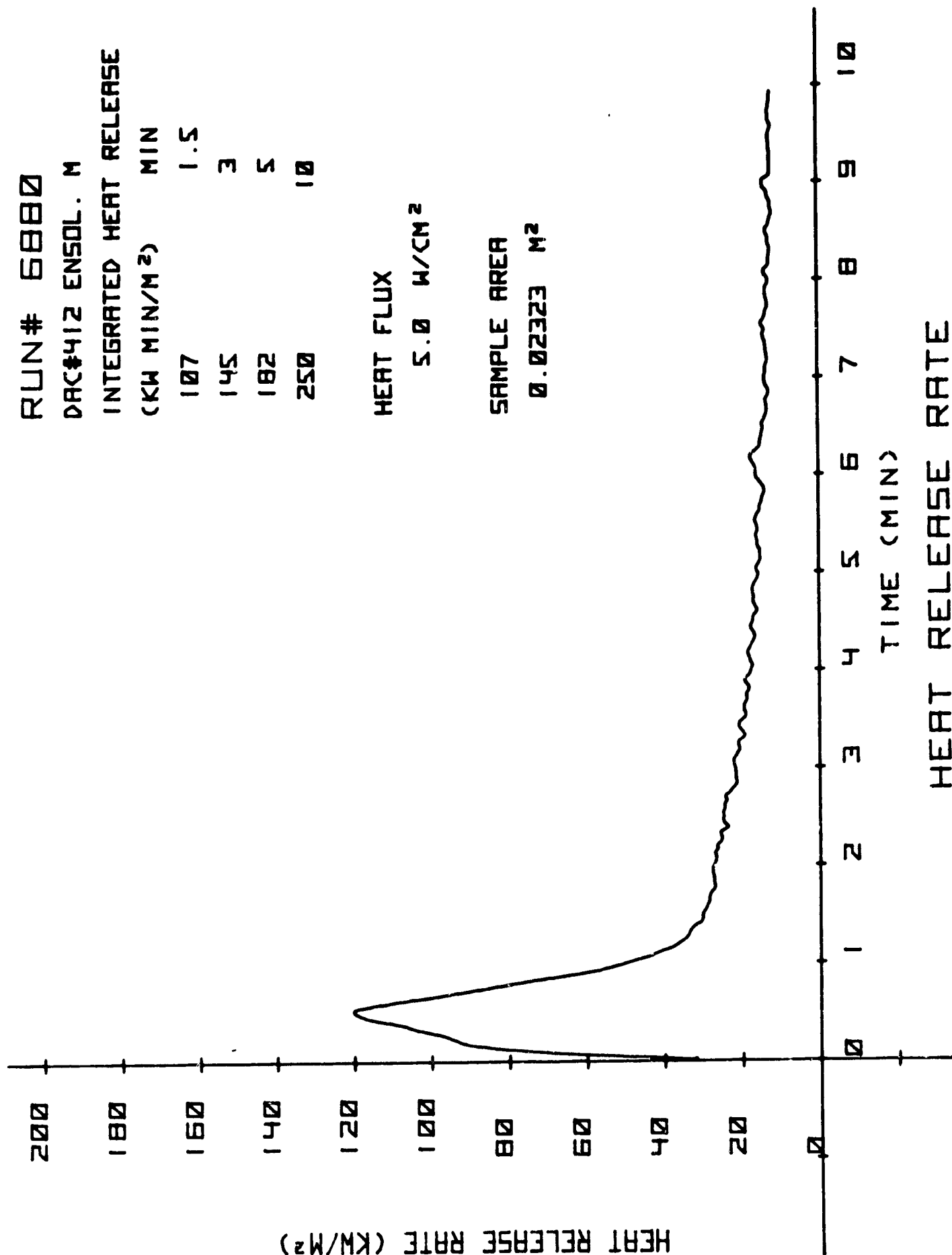


RUN# 6880
 DAC#412 ENSOL. M
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN

| | |
|-----|-----|
| 107 | 1.5 |
| 145 | 3 |
| 182 | 5 |
| 250 | 10 |

HEAT FLUX
 5.0 W/CM²

SAMPLE AREA
 0.02323 M²



RUN# 6780

DAC#414 ARIEX FORM

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

72 1.5

91 3

107 5

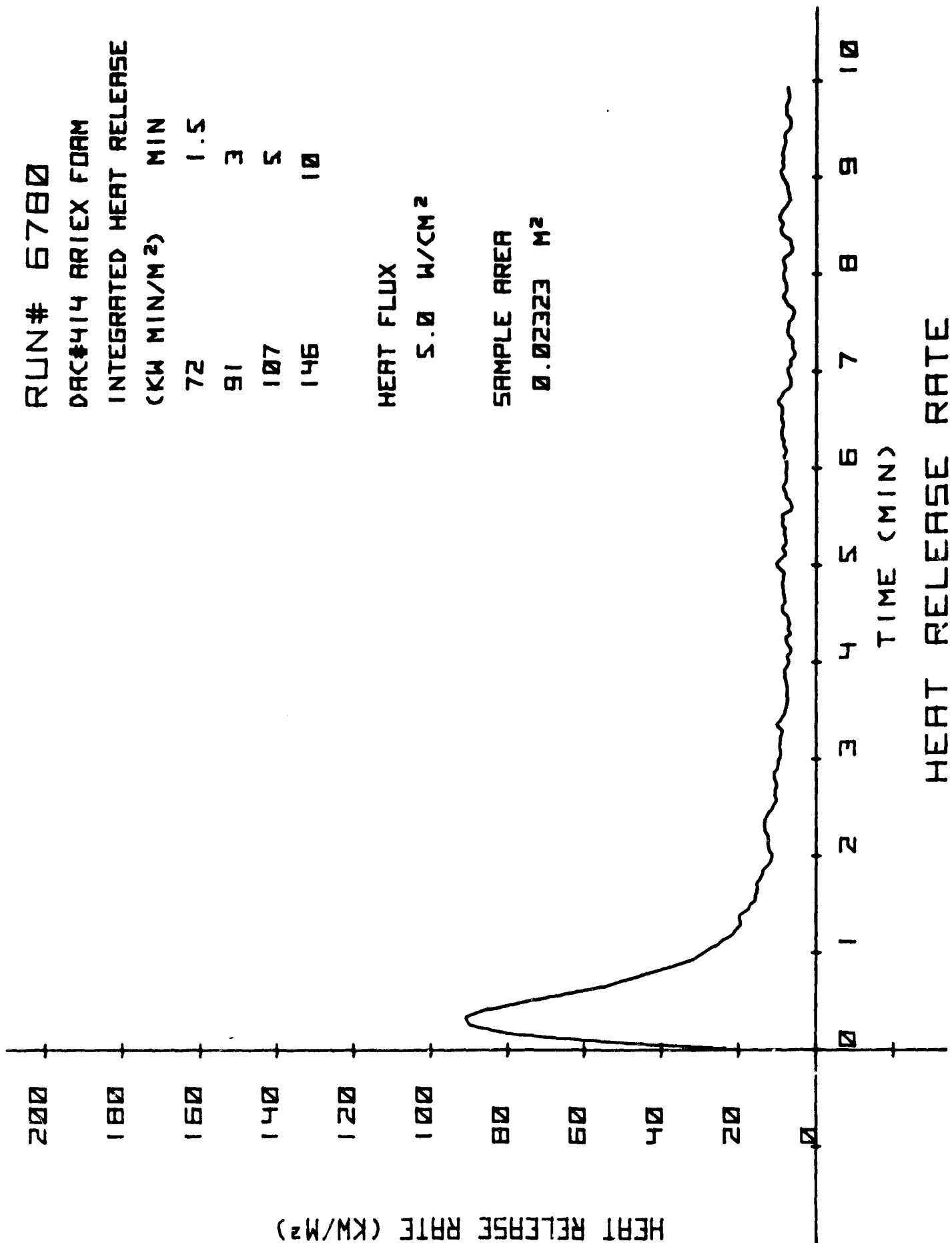
146 10

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE

RUN# 6680

DAC#323 POLYIMIDE F.

INTEGRATED HEAT RELEASE

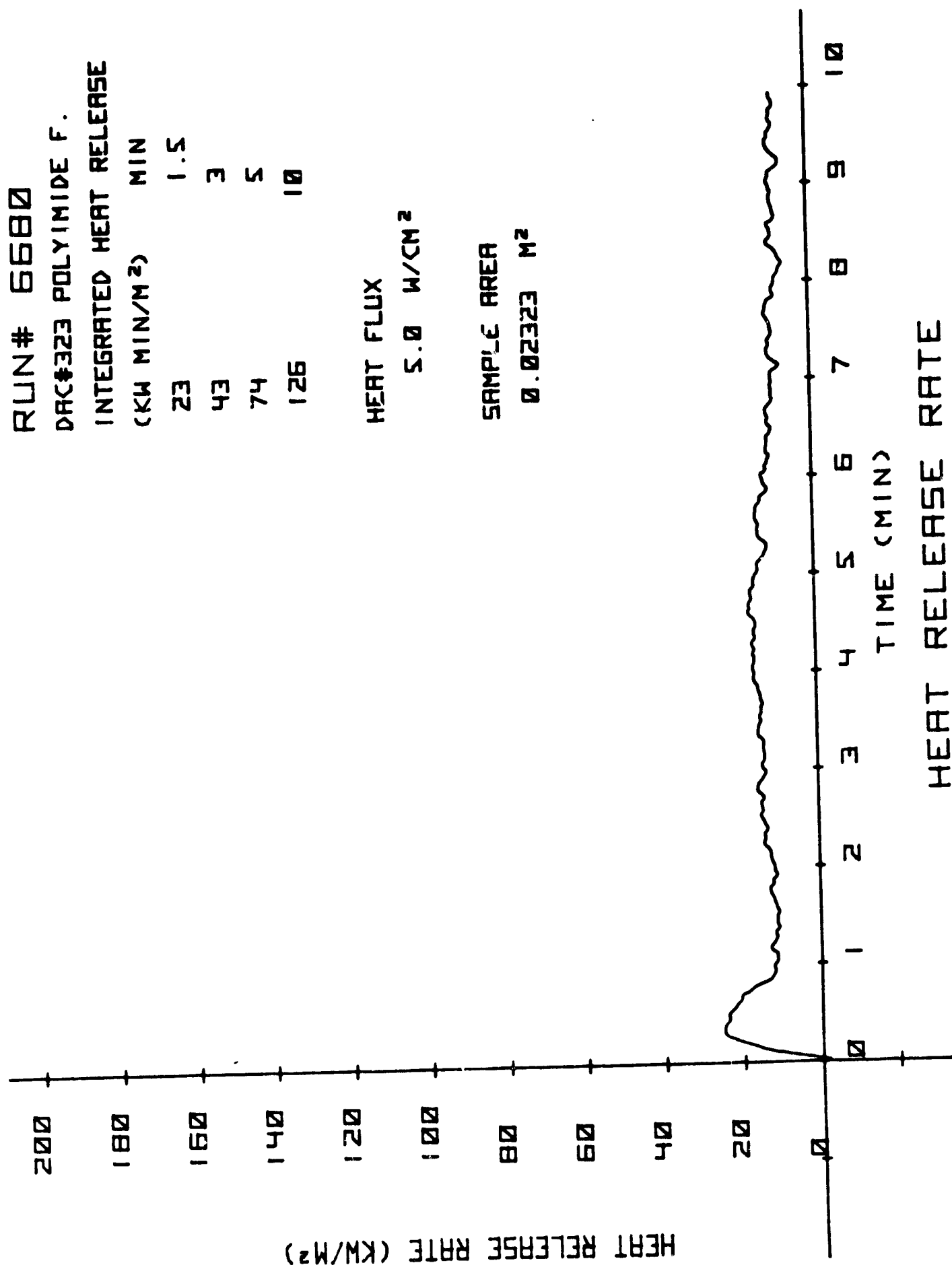
| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 23 | 1.5 |
| 43 | 3 |
| 74 | 5 |
| 126 | 10 |

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²

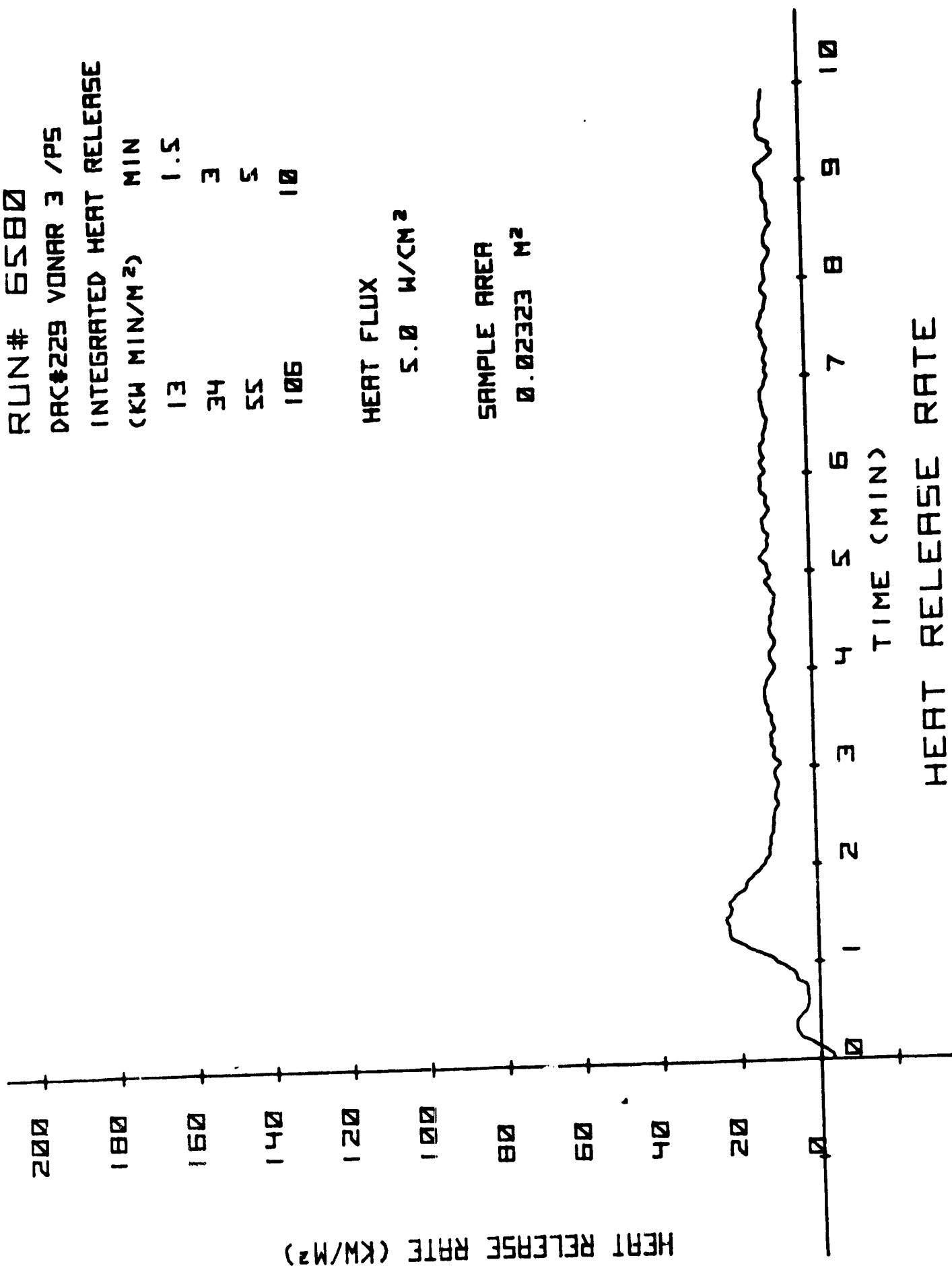


RUN# 6580
 DAC#229 VONAR 3 /PS
 INTEGRATED HEAT RELEASE

| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 13 | 1.5 |
| 34 | 3 |
| 55 | 5 |
| 106 | 10 |

HEAT FLUX
 5.0 W/CM²

SAMPLE AREA
 0.02323 M²



RUN# 6480

DAC#117 SED. BLUE

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

60 1.5

78 3

96 5

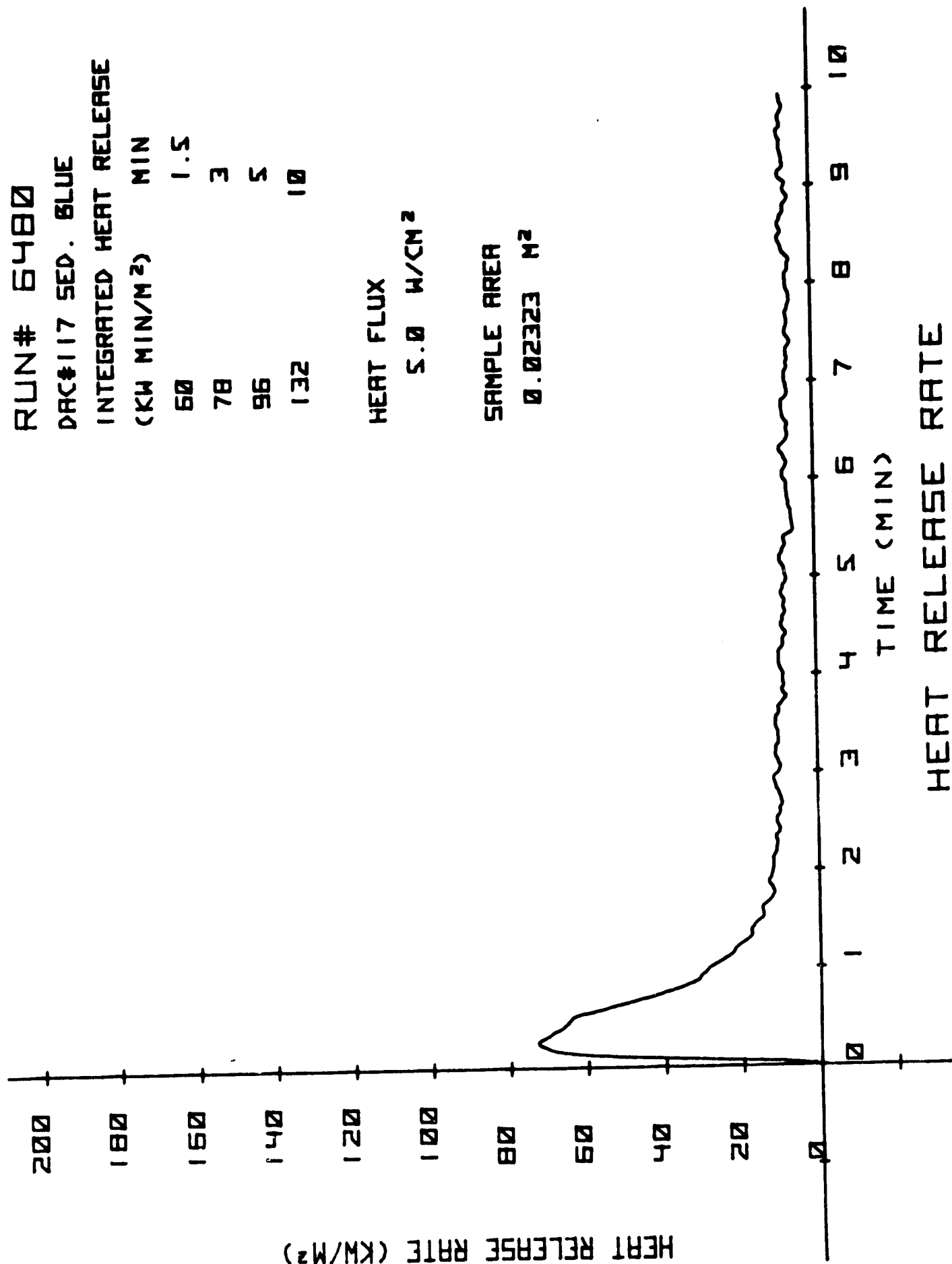
132 10

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE

RUN# 6380

DAC#228 COTTON M.

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

13 1.5

21 3

33 5

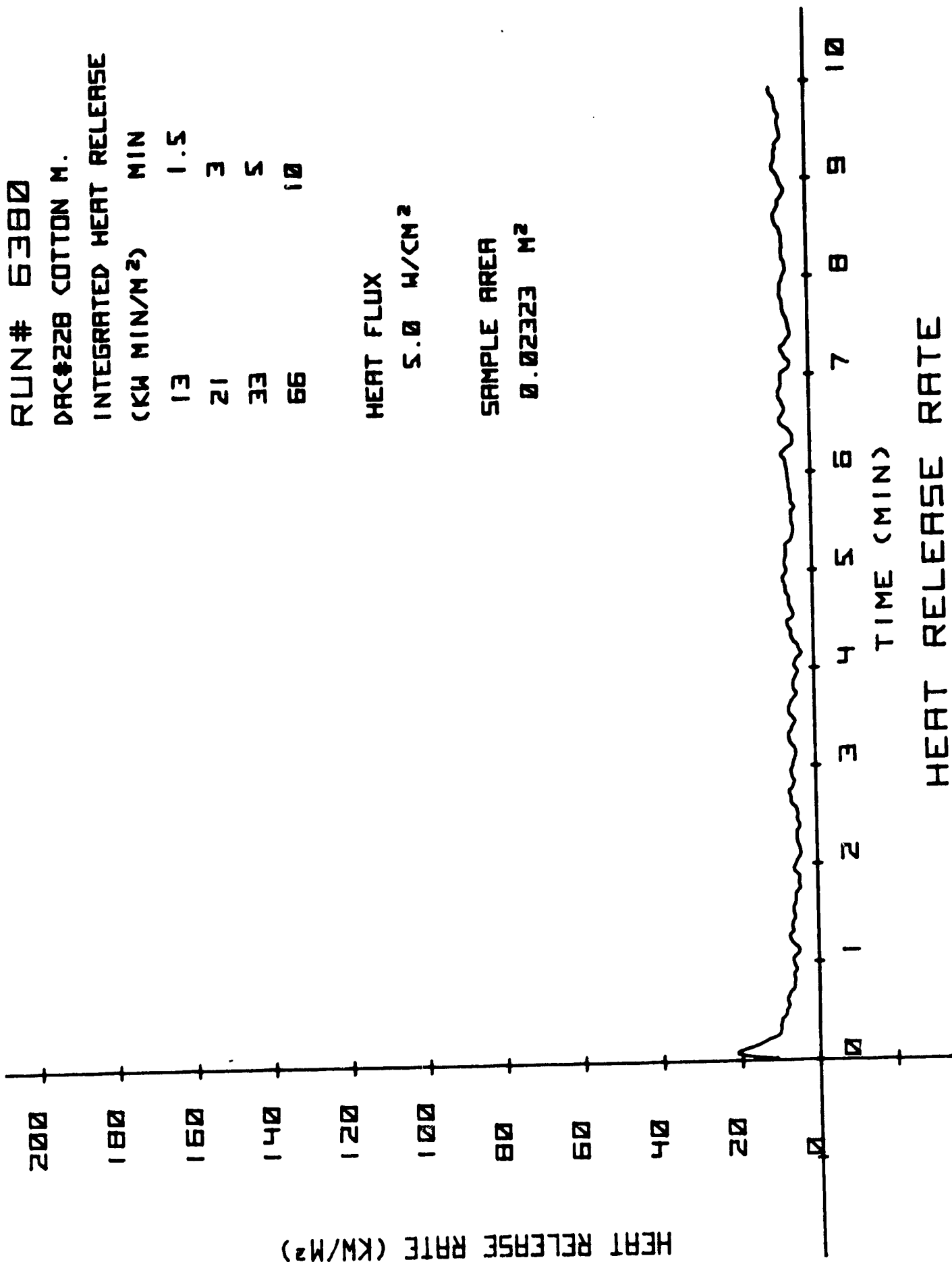
66 10

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

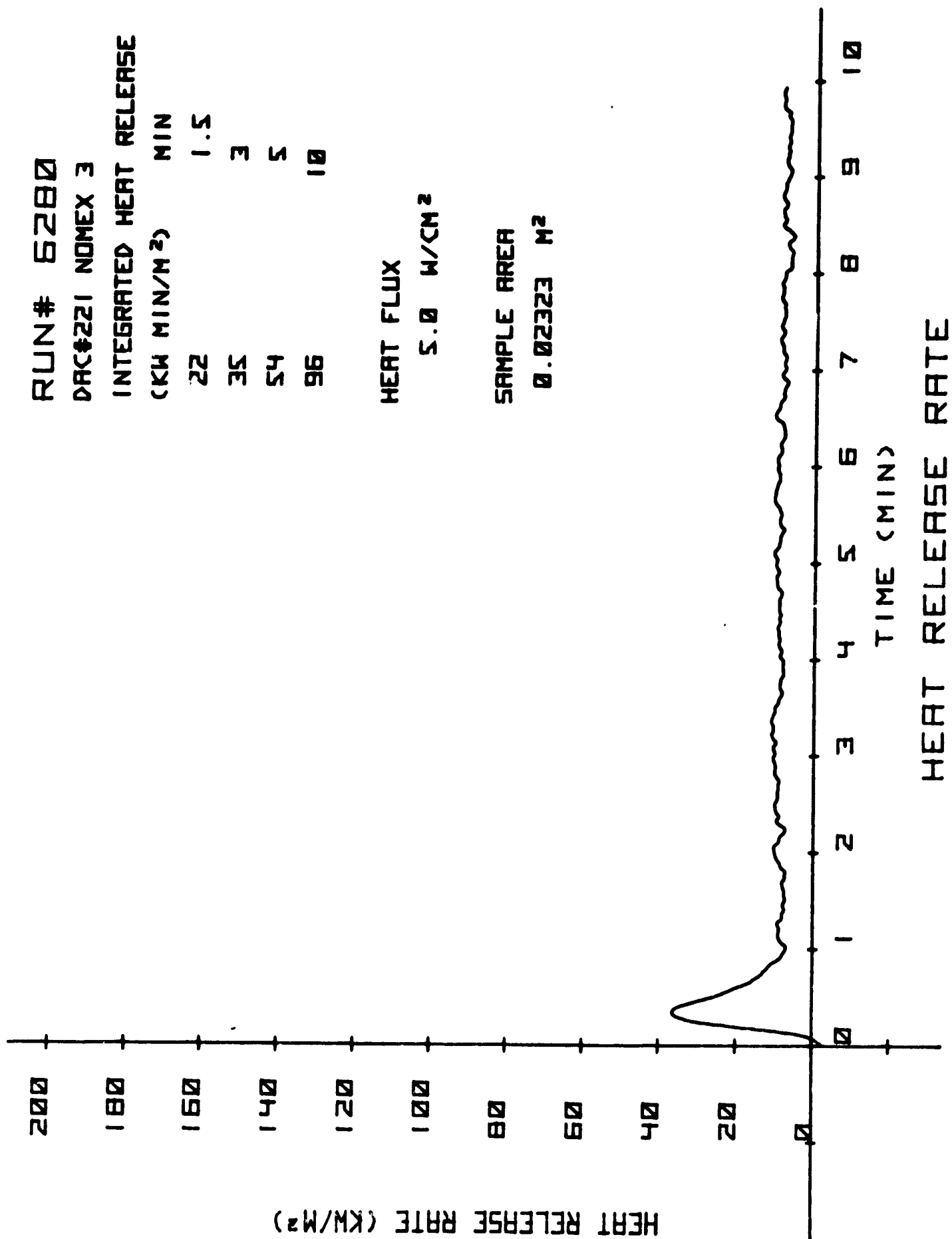
0.02323 M²



RUN# 6280
 DAC#221 NOMEX 3
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 22 1.5
 35 3
 54 5
 96 10

HEAT FLUX
 5.0 W/CM²

SAMPLE AREA
 0.02323 M²



HEAT RELEASE RATE

RUN# 6180

BASELINE RUN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-2 1.5

-2 3

2 5

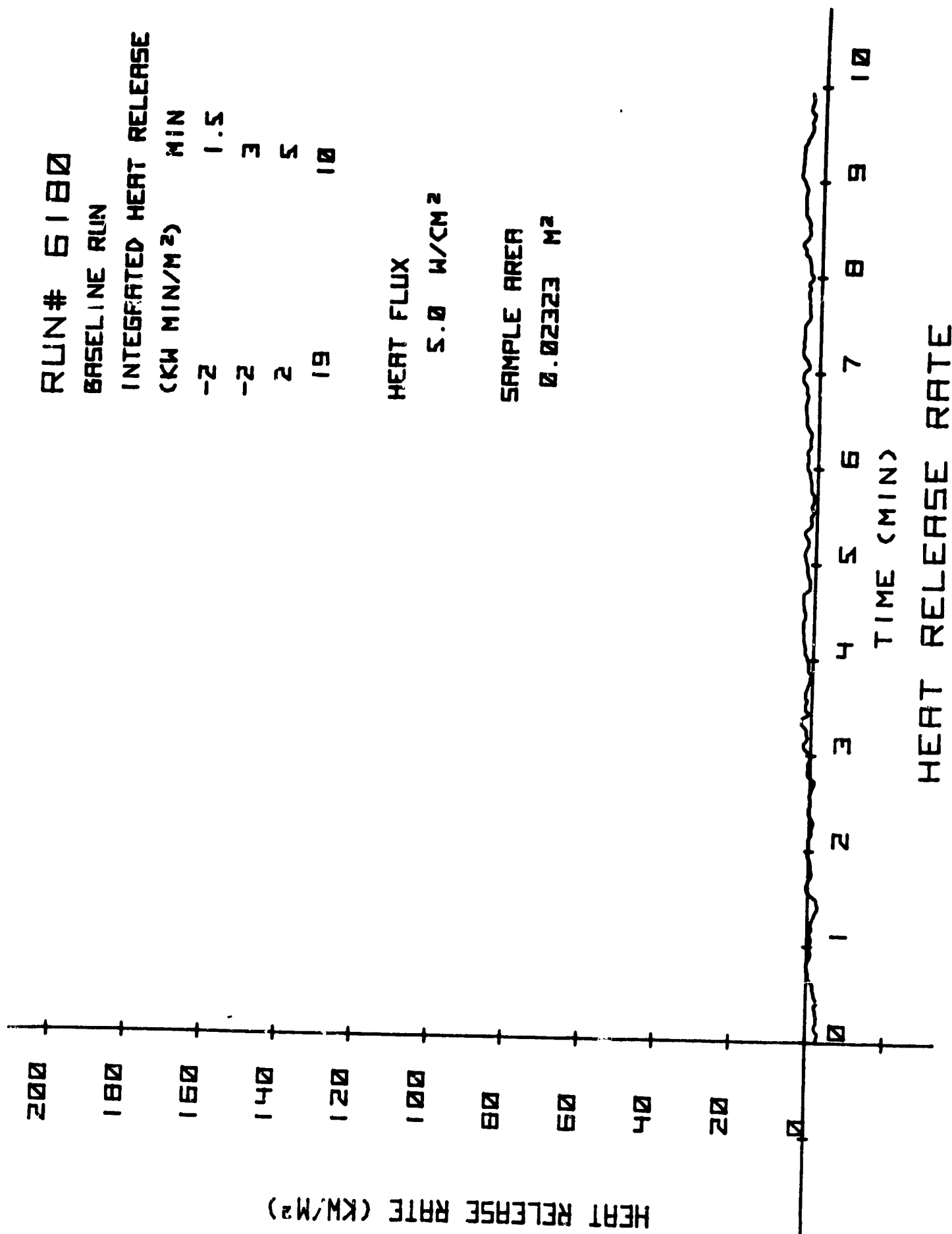
19 10

HEAT FLUX

5.0 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE (KW/M²)

TIME (MIN)

HEAT RELEASE RATE

RUN# 6080

DAC#322 URETHANE F.

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

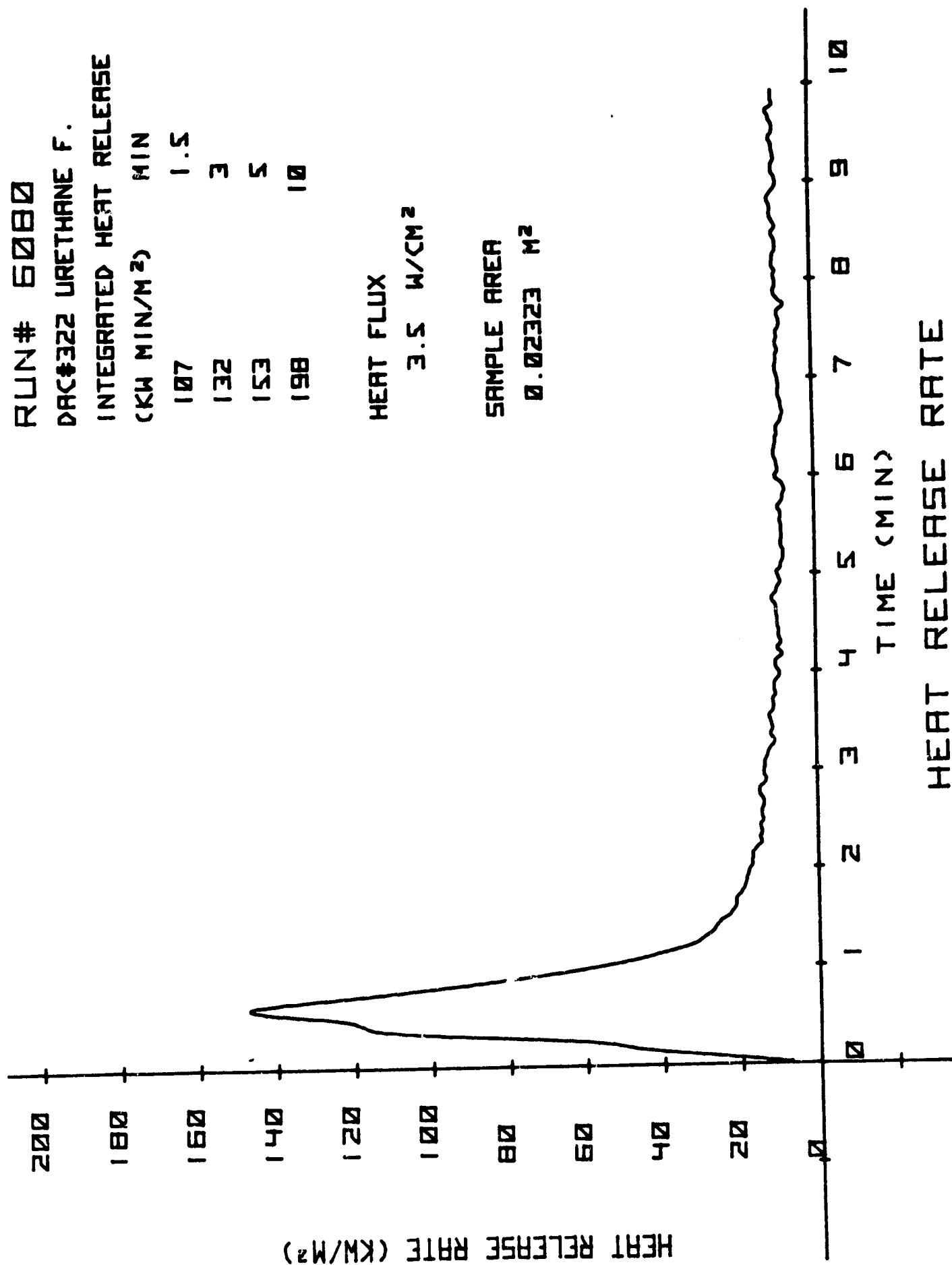
| | |
|-----|-----|
| 107 | 1.5 |
| 132 | 3 |
| 153 | 5 |
| 198 | 10 |

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE (KW/M²)

TIME (MIN)

HEAT RELEASE RATE

RUN# 5980

DAC#414 ARIEX FORM

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

74 1.5

89 3

98 5

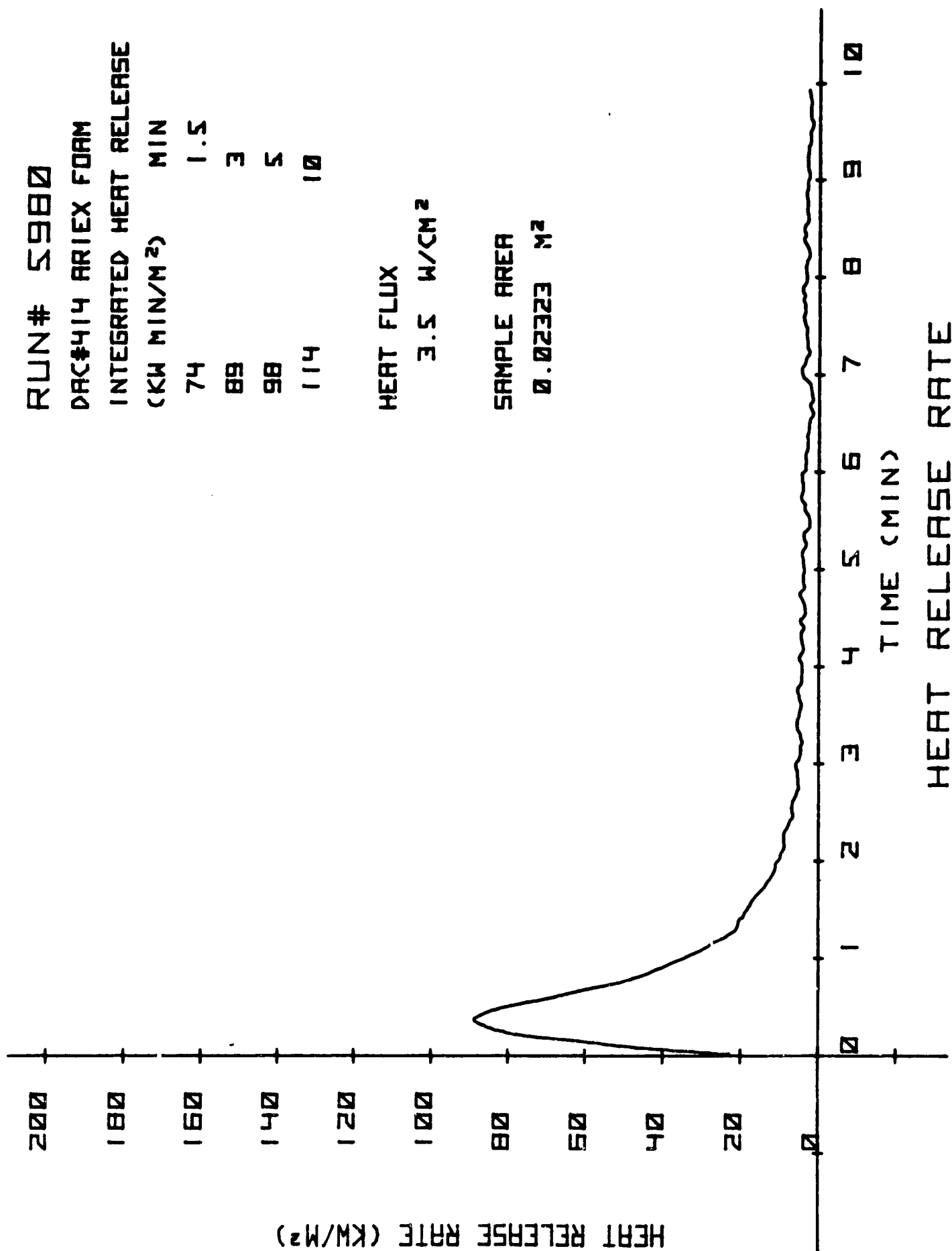
114 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 5880

DRC#323 P 1

INTEGRATED HEAT RELEASE

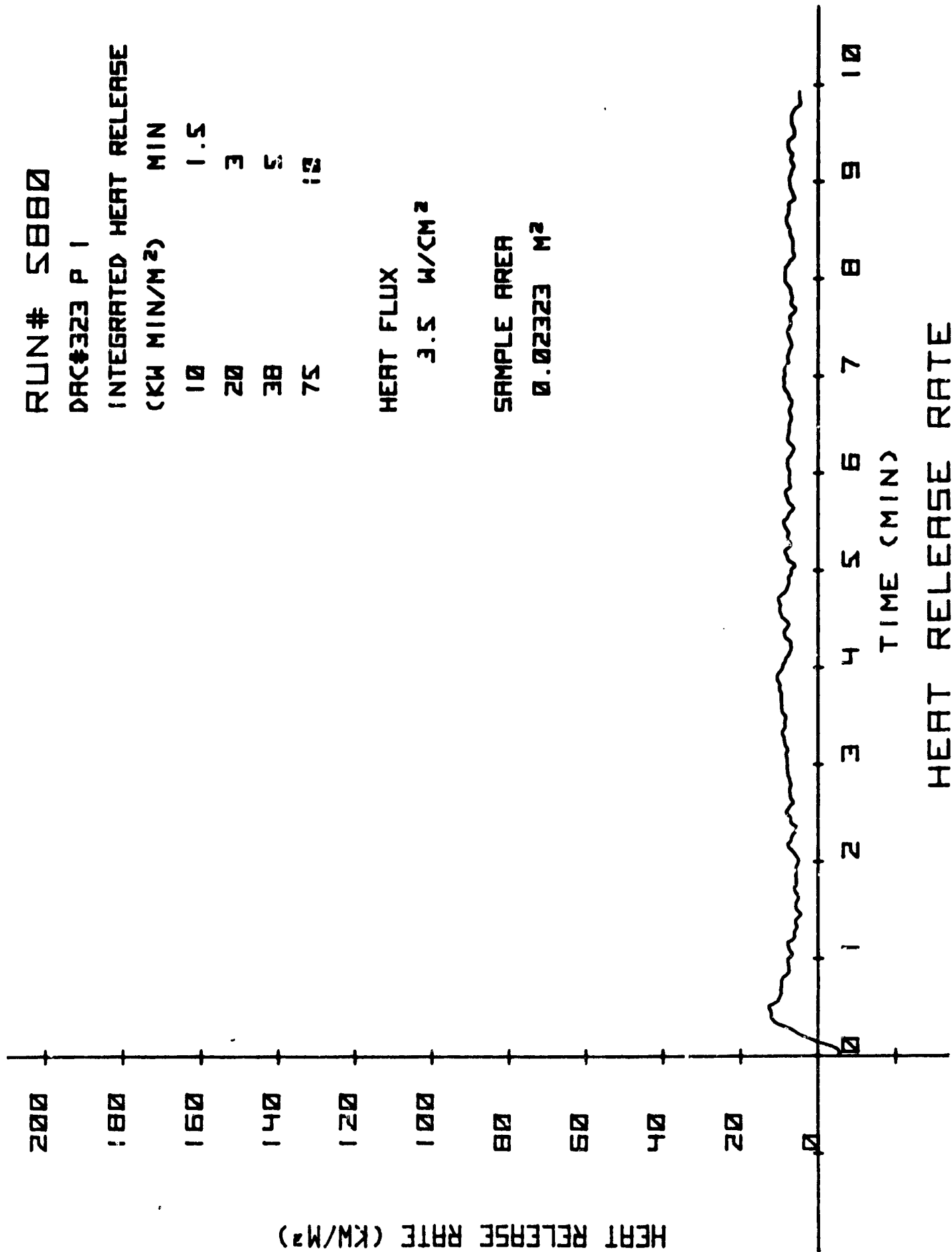
| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 10 | 1.5 |
| 20 | 3 |
| 30 | 5 |
| 75 | 12 |

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 5780

BASELINE RUN(AL203)

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-5 1.5

-6 3

-4 5

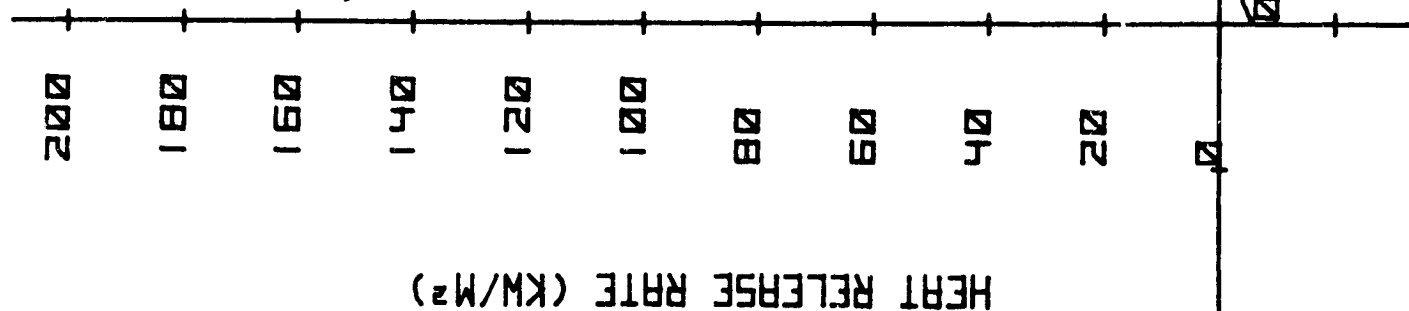
3 10

HEAT FLUX

3.5 W/CM²

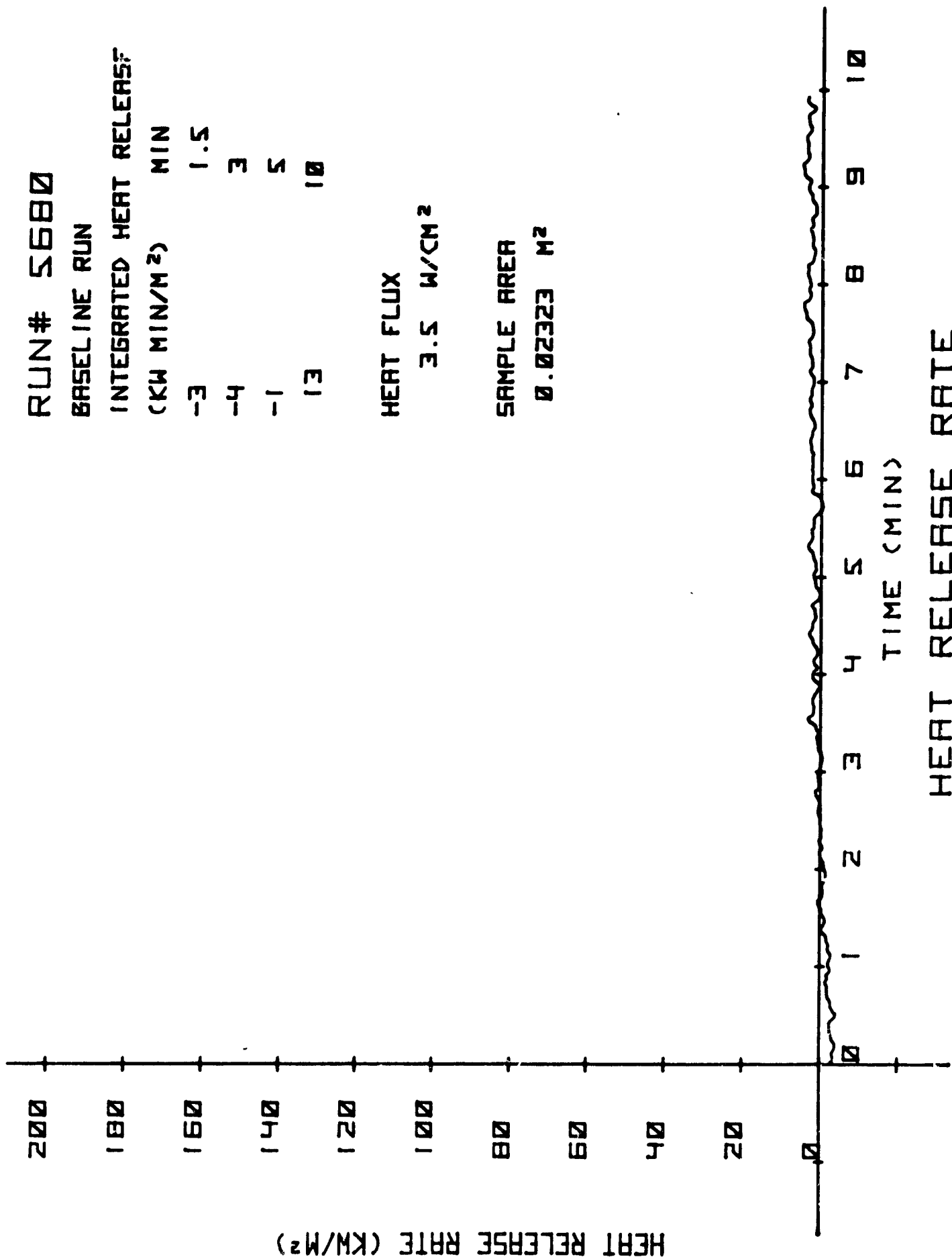
SAMPLE AREA

0.02323 M²



TIME (MIN)

HEAT RELEASE RATE



RUN# 5680

BASELINE RUN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-3 1.5

-4 3

-1 5

13 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²

RUN# 5580

BASELINE RUN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-5 1.5

-8 3

-6 5

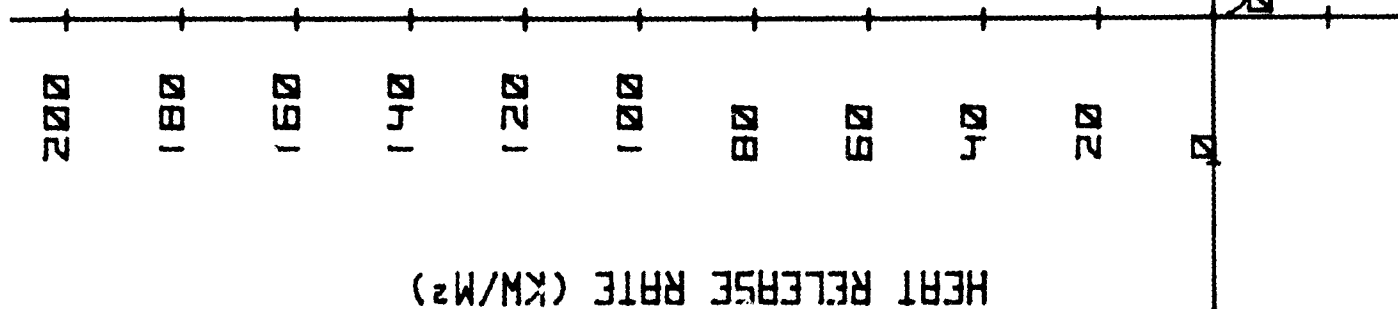
6 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE

RUN# 5480

DRC#229 VONAR 3 /PS

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-2 1.5

8 3

16 5

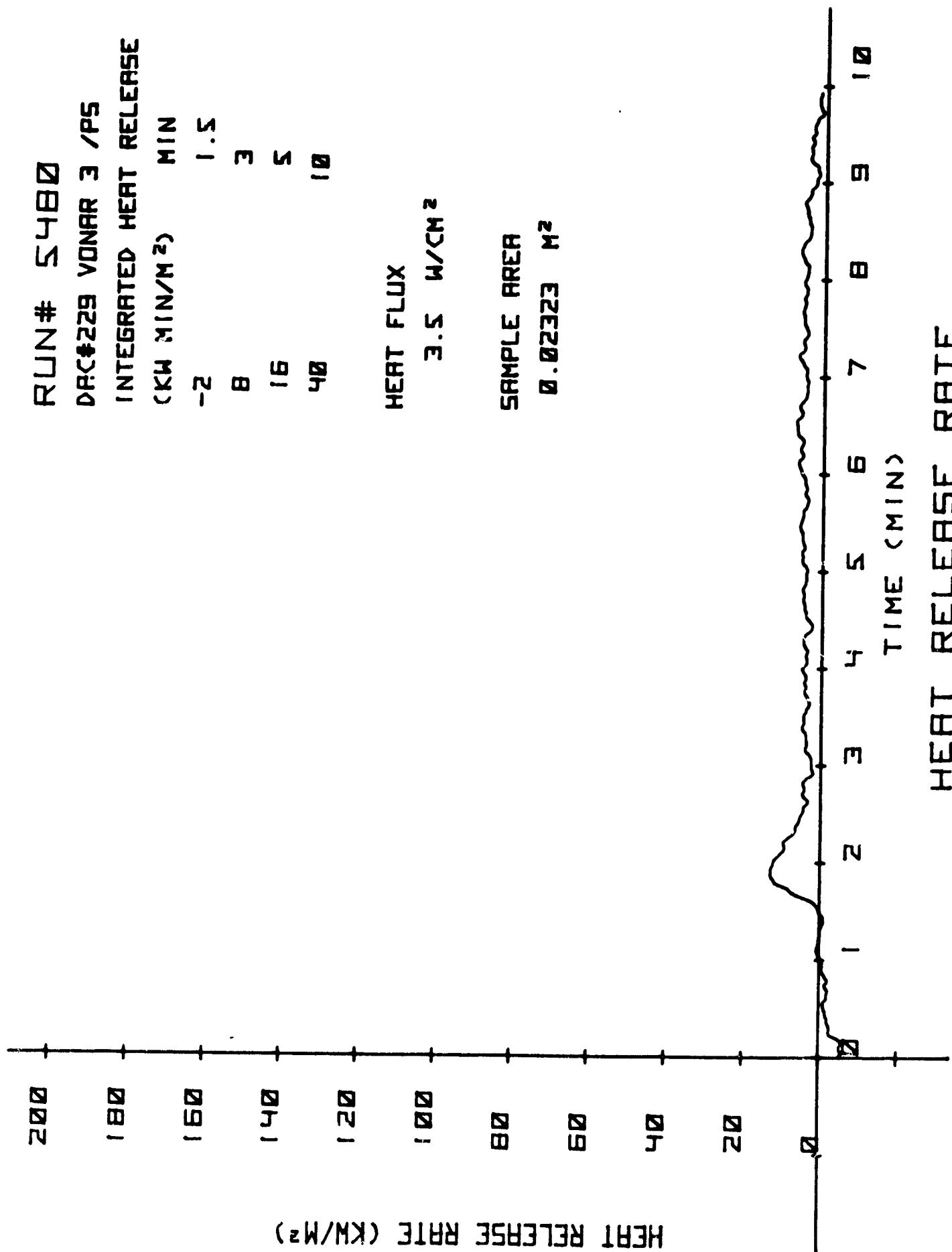
40 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²



HEAT RELEASE RATE (KW/M²)

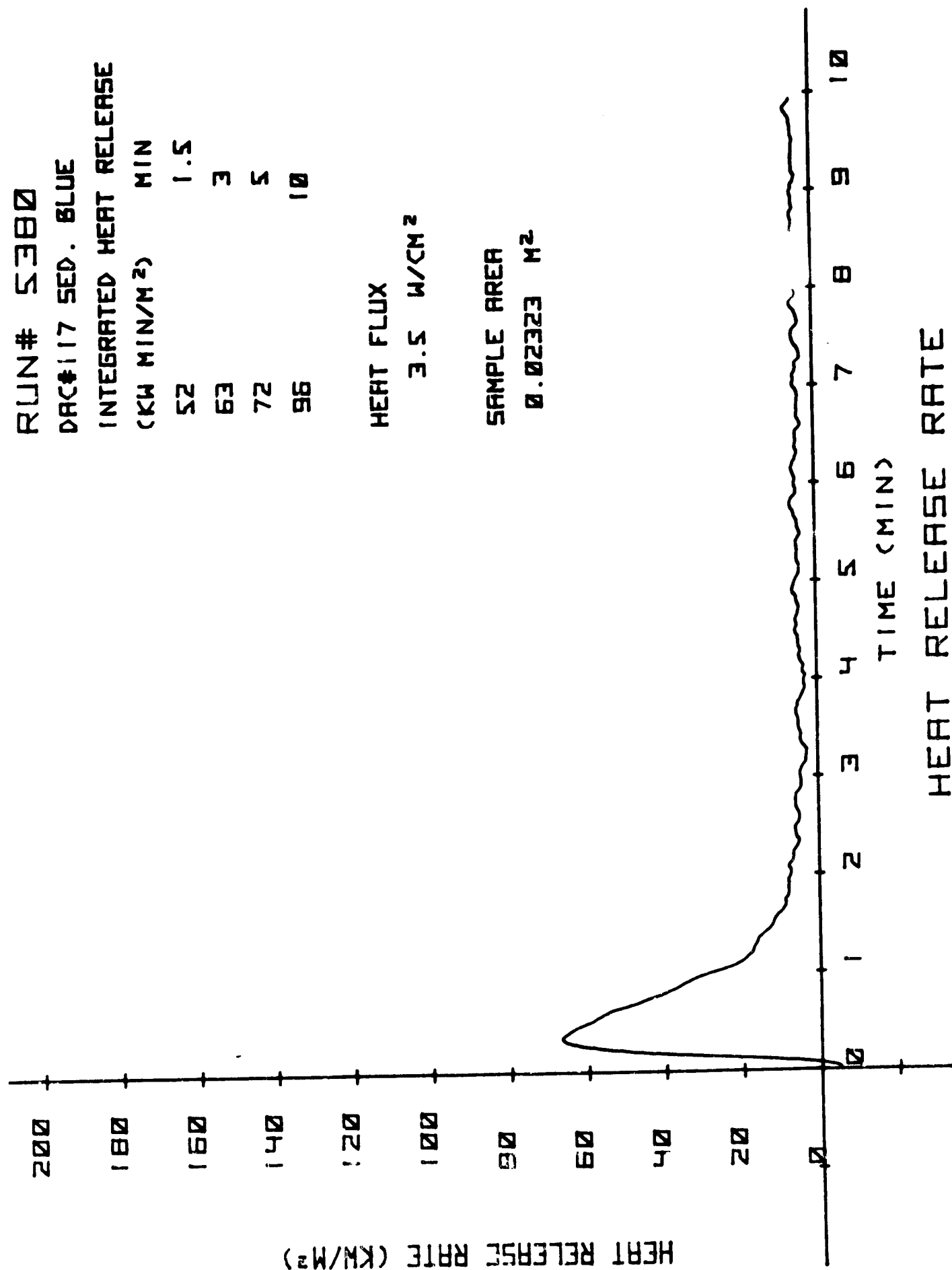
TIME (MIN)

HEAT RELEASE RATE

RUN# 5380
 DAC#117 SED. BLUE
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 52 1.5
 63 3
 72 5
 96 10

HEAT FLUX
 3.5 W/CM²

SAMPLE AREA
 0.02323 M²



RUN# 5280

DAC#221 NOHEX 3

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

3 1.5

3 3

6 5

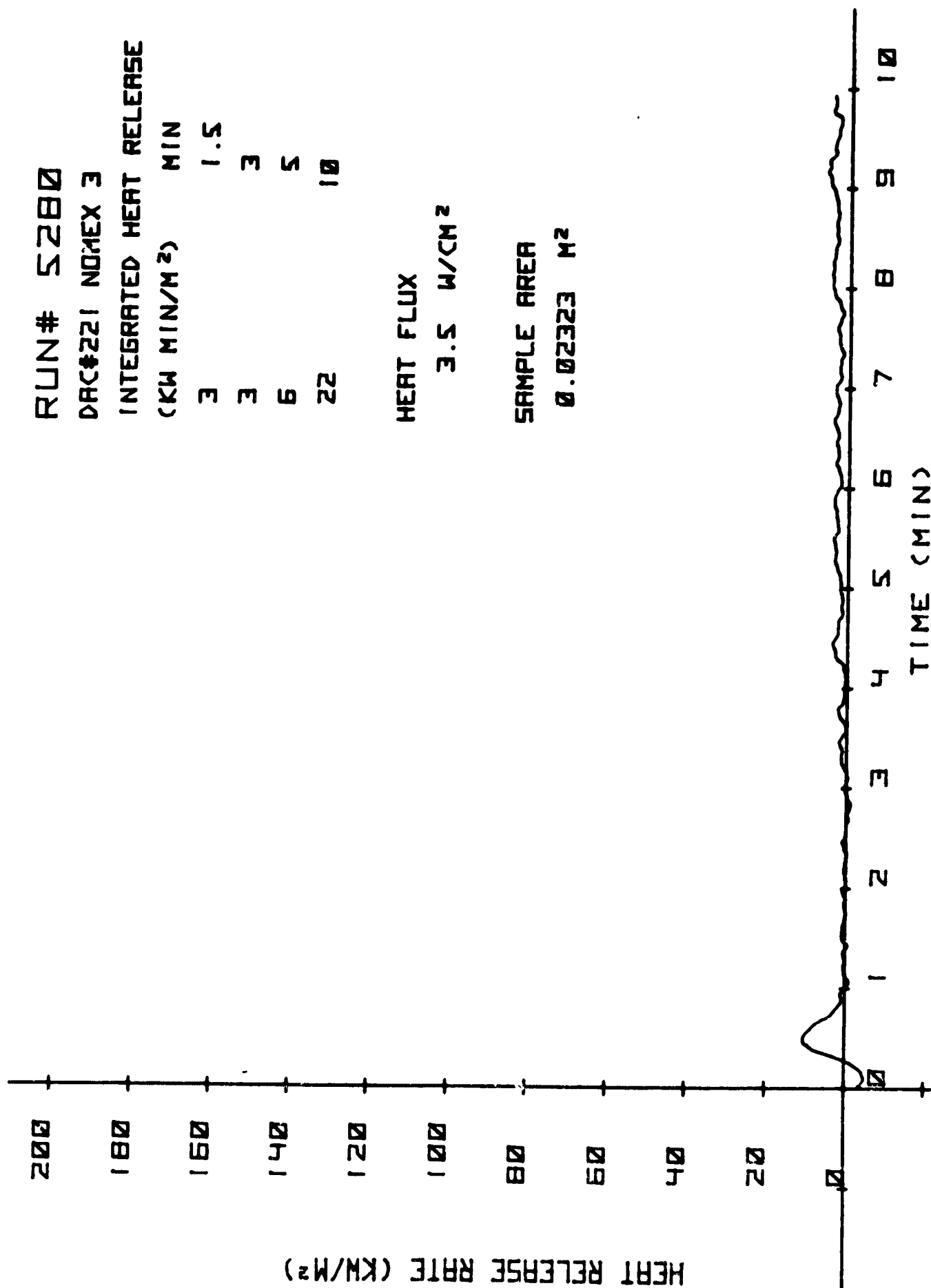
22 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.02323 M²

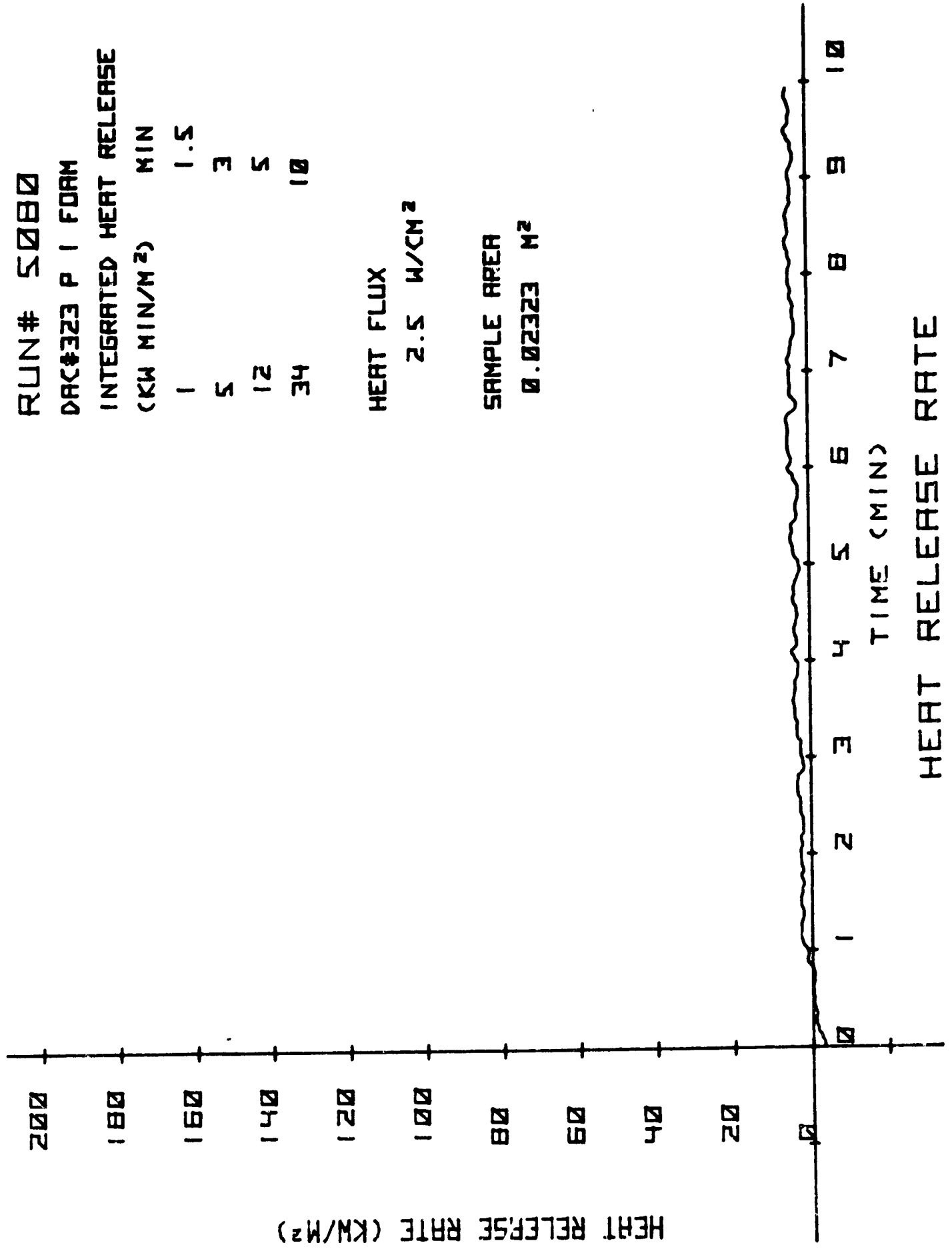


HEAT RELEASE RATE

RUN# 5080
 DAC#323 P 1 FORM
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 1 1.5
 5 3
 12 5
 34 10

HEAT FLUX
 2.5 W/CM²

SAMPLE AREA
 0.02323 M²



RUN# 4980

DAC#414 ARIEX FORM

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

81 1.5

102 3

113 5

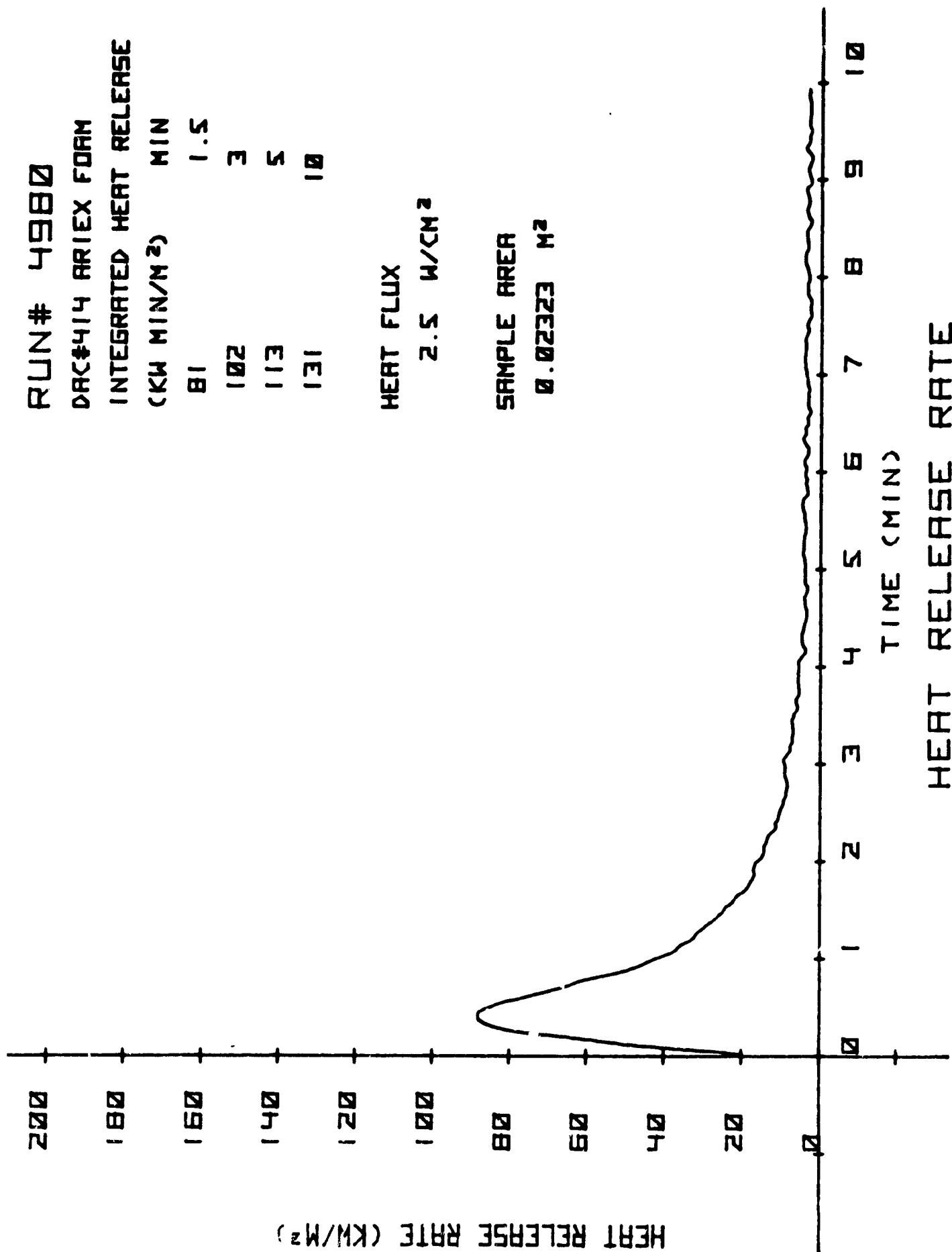
131 10

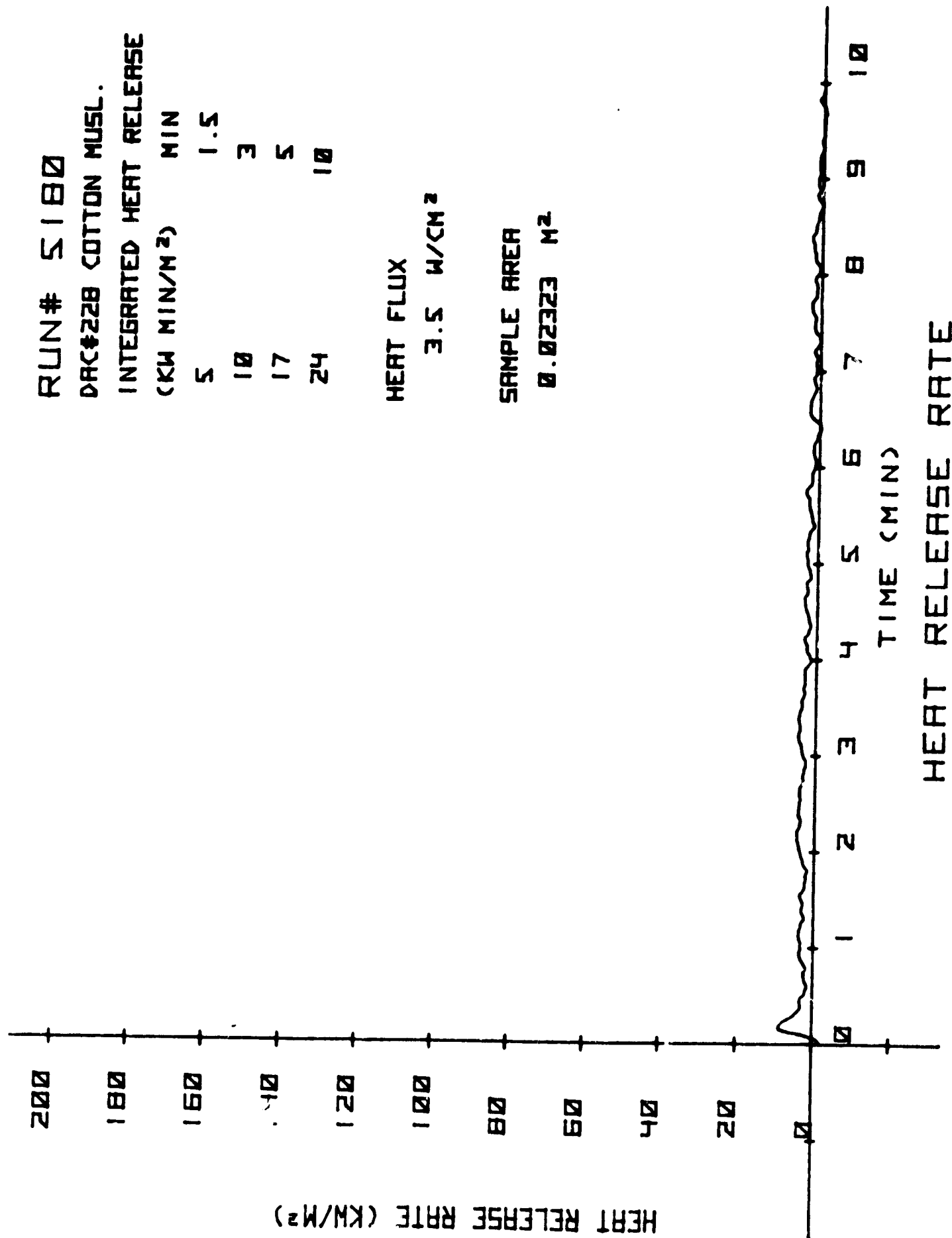
HEAT FLUX

2.5 W/CM²

SAMPLE AREA

0.02323 M²



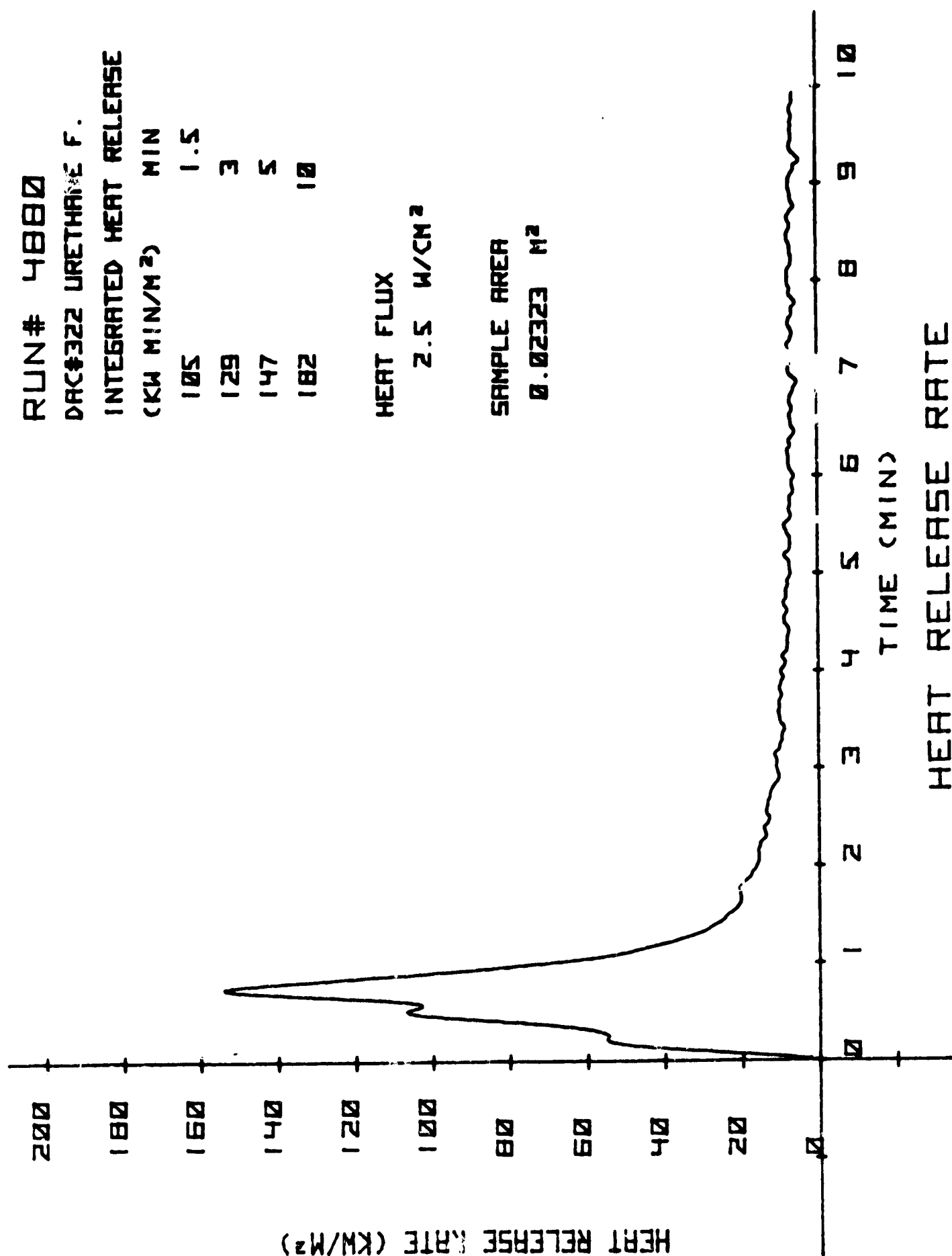


RUN# 4880
 DAC#322 URETHANE F.
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN

| | |
|-----|-----|
| 105 | 1.5 |
| 129 | 3 |
| 147 | 5 |
| 182 | 10 |

HEAT FLUX
 2.5 W/CN²

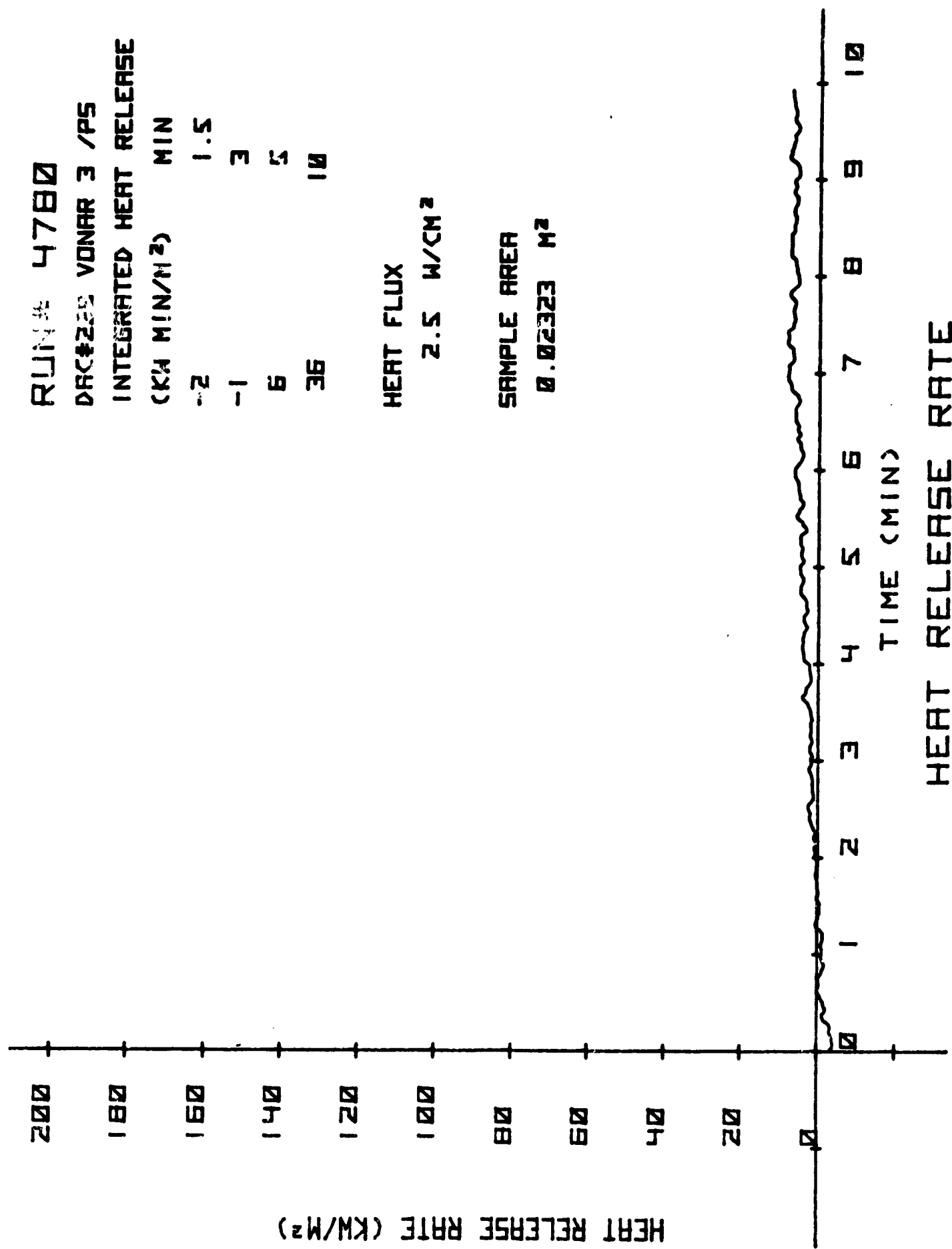
SAMPLE AREA
 0.02323 M²



HEAT RELEASE RATE (KW/M²)

TIME (MIN)

HEAT RELEASE RATE



RUN# 4780
 DRG#222 VONAR 3 /PS
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 -2 1.5
 -1 3
 6 5
 36 10

HEAT FLUX
 2.5 W/CN²

SAMPLE AREA
 0.02323 M²

2-2

RUN# 4680

BASELINE RUN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

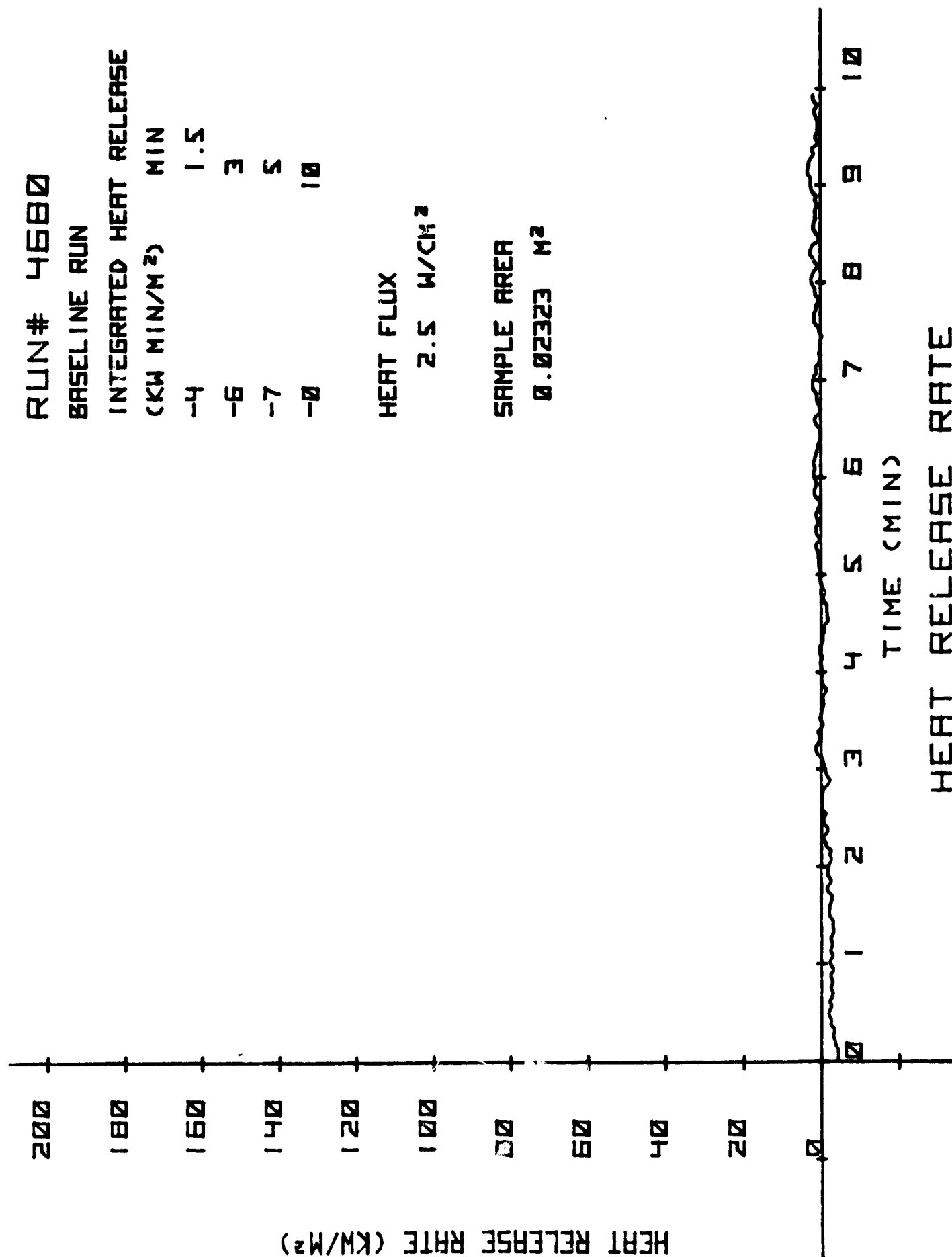
| | |
|----|-----|
| -4 | 1.5 |
| -6 | 3 |
| -7 | 5 |
| -8 | 10 |

HEAT FLUX

2.5 W/CM²

SAMPLE AREA

0.02323 M²



RUN# 4580

DAC#228 COT. MUSLIN

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

-4 1.5

-7 3

-9 5

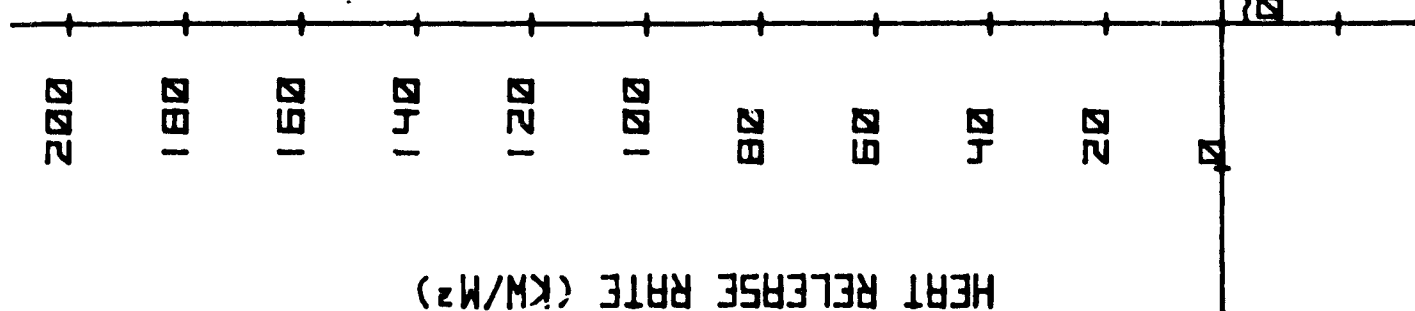
-12 19

HEAT FLUX

2.5 W/CM²

SAMPLE AREA

0.02323 M²



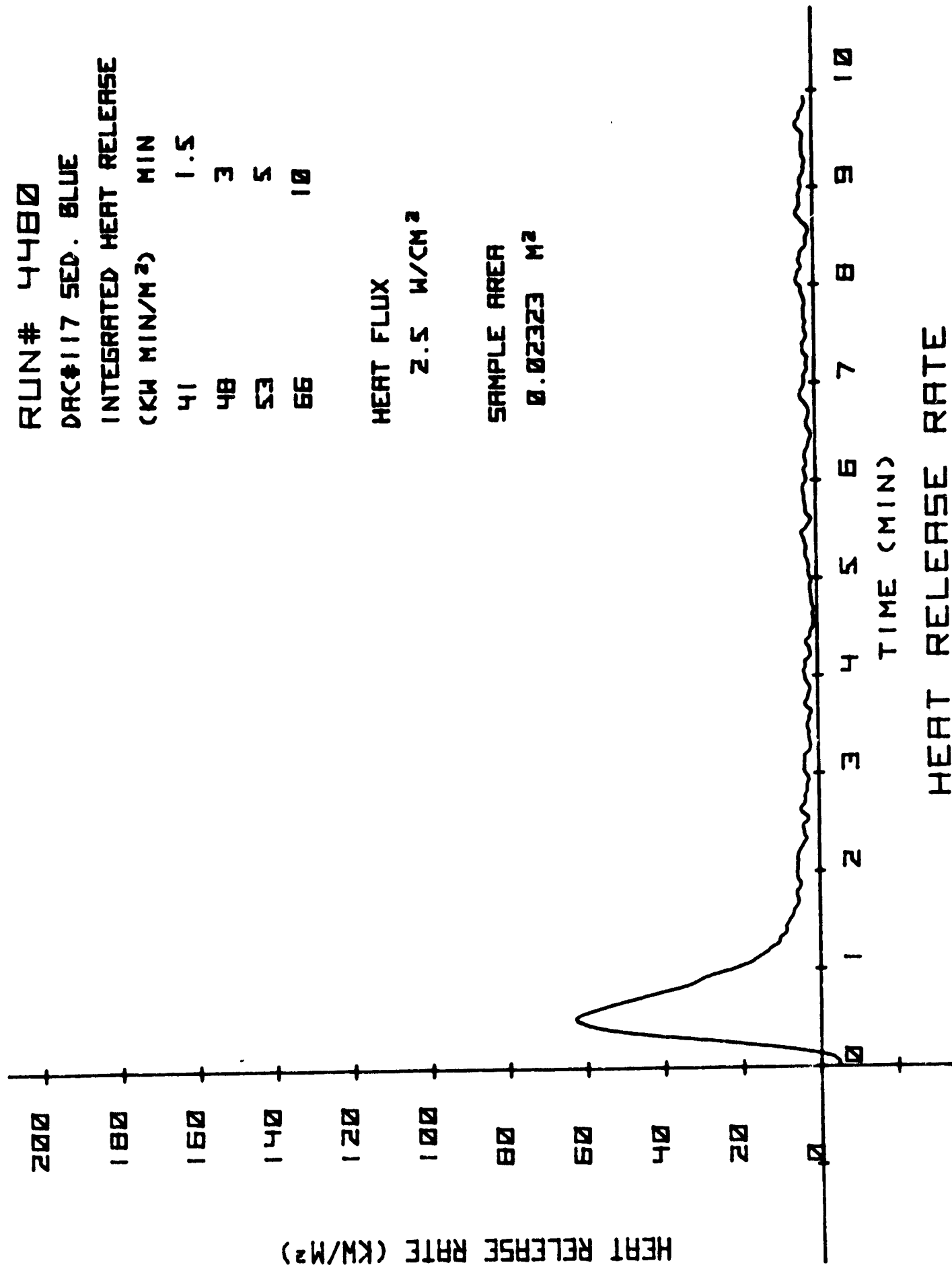
HEAT RELEASE RATE

RUN# 4480
 DRC#117 SED. BLUE
 INTEGRATED HEAT RELEASE

| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 41 | 1.5 |
| 48 | 3 |
| 53 | 5 |
| 66 | 10 |

HEAT FLUX
 2.5 W/CM²

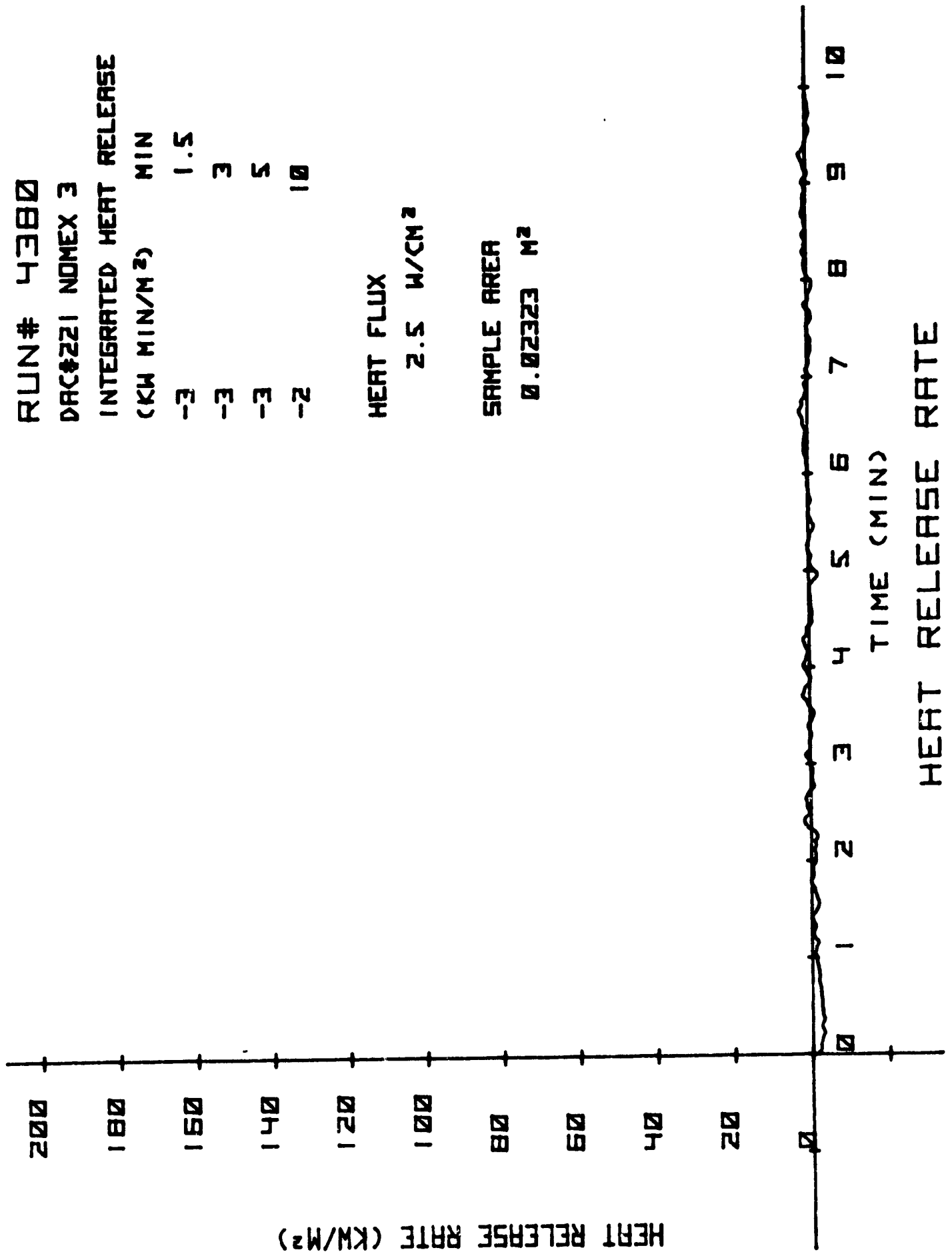
SAMPLE AREA
 0.02323 M²



RUN# 4380
 DRC#221 NOMEX 3
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 -3 1.5
 -3 3
 -3 5
 -2 10

HEAT FLUX
 2.5 W/CM²

SAMPLE AREA
 0.02323 M²



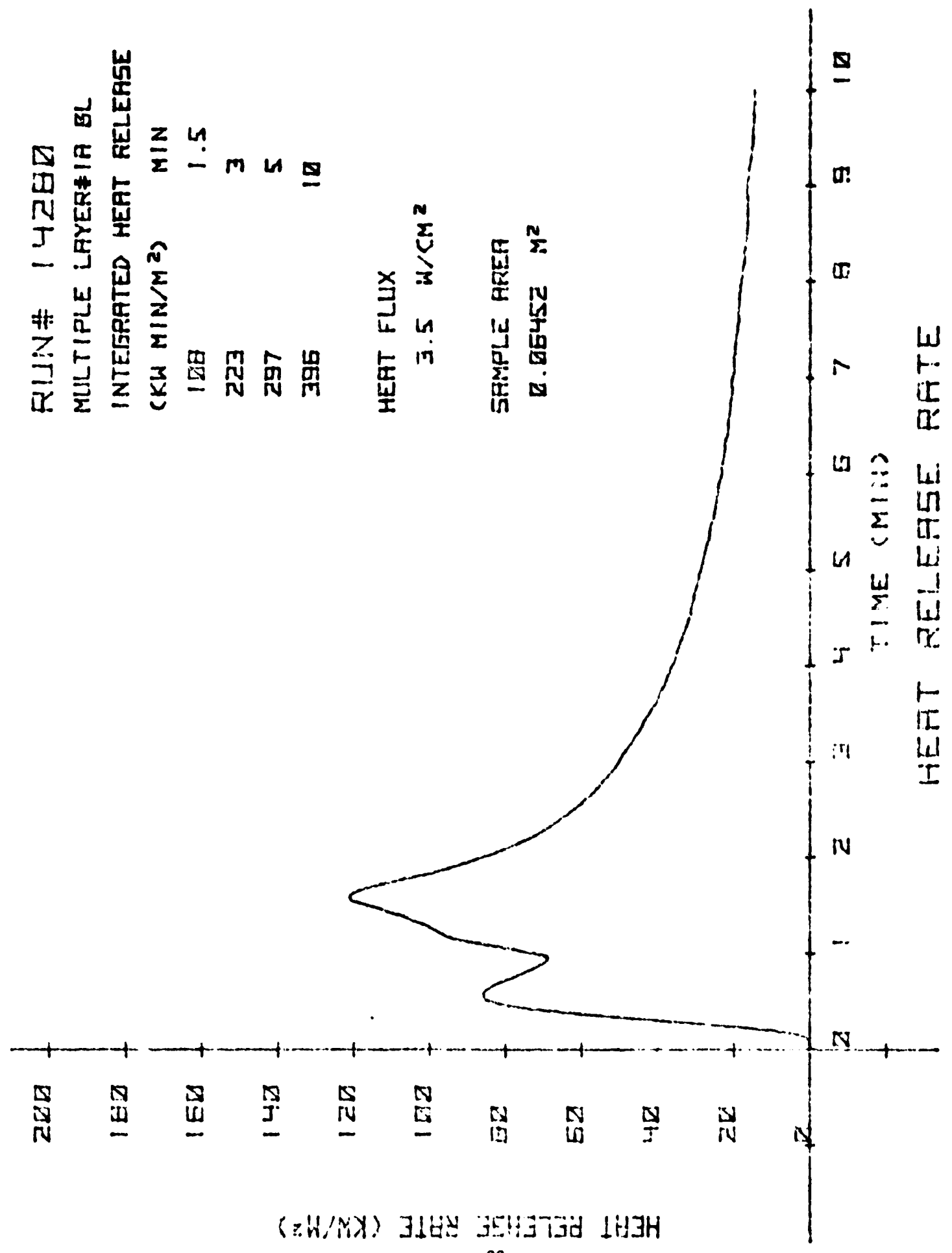
HEAT RELEASE RATE

RUN# 14280
 MULTIPLE LAYER#1A BL
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN

| | |
|-----|-----|
| 108 | 1.5 |
| 223 | 3 |
| 297 | 5 |
| 396 | 10 |

HEAT FLUX
 3.5 W/CM²

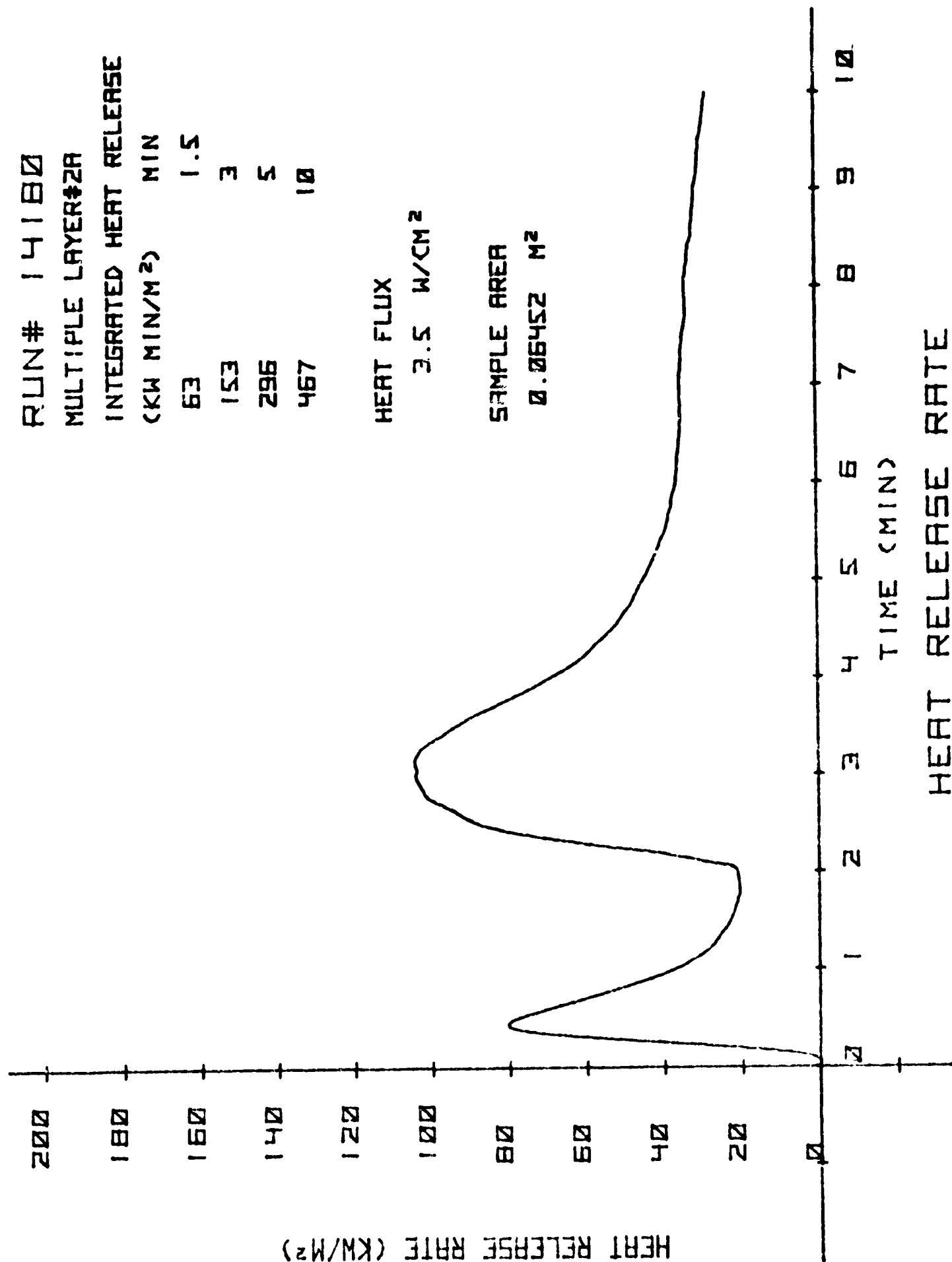
SAMPLE AREA
 0.06452 M²



RUN# 14180
 MULTIPLE LAYER#2A
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN

| | |
|-----|-----|
| 63 | 1.5 |
| 153 | 3 |
| 296 | 5 |
| 467 | 10 |

HEAT FLUX
 3.5 W/CM²
 SAMPLE AREA
 0.06452 M²



HEAT RELEASE RATE

RUN# 14080

MULTIPLE LAYER 3A

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

50 1.5

108 3

266 5

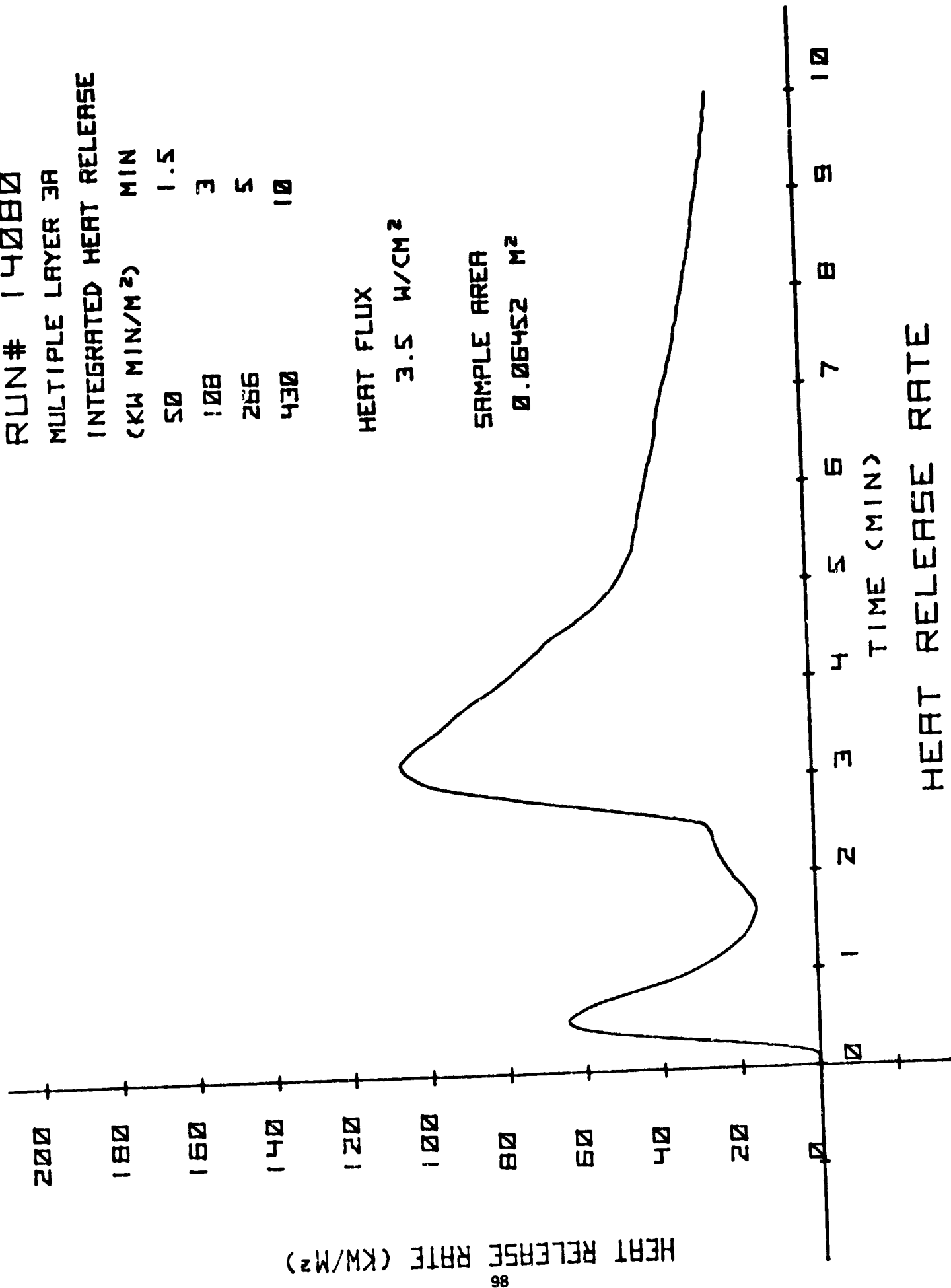
430 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

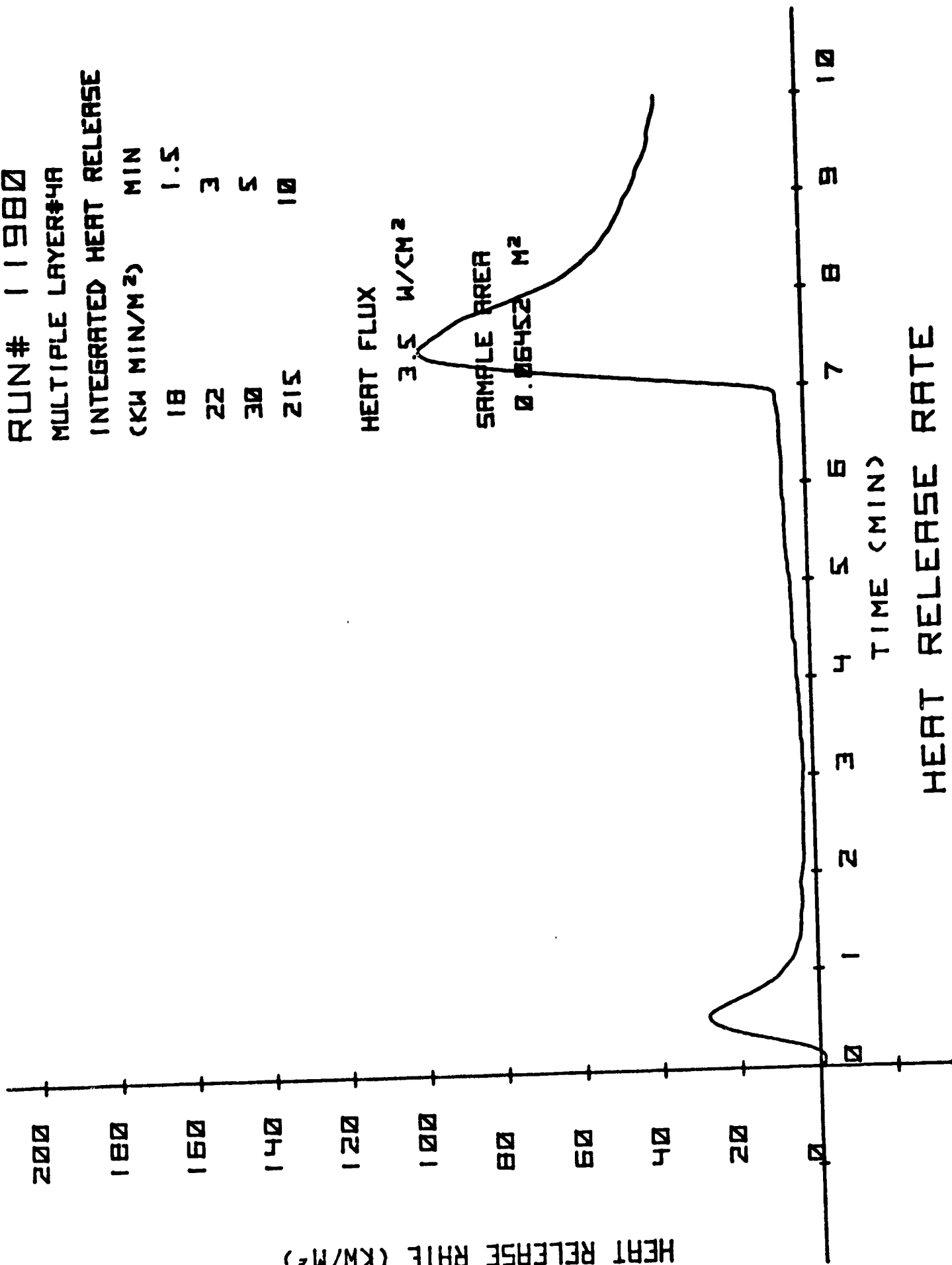
0.06452 M²



RUN# 11980
 MULTIPLE LAYER#4A
 INTEGRATED HEAT RELEASE

| (KW MIN/M ²) | MIN |
|--------------------------|-----|
| 18 | 1.5 |
| 22 | 3 |
| 30 | 5 |
| 215 | 10 |

HEAT RELEASE RATE (KW/M²)



TIME (MIN)

HEAT RELEASE RATE

RUN# 14380

MULTIPLE LAYER#5A

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

24 1.5

44 3

216 5

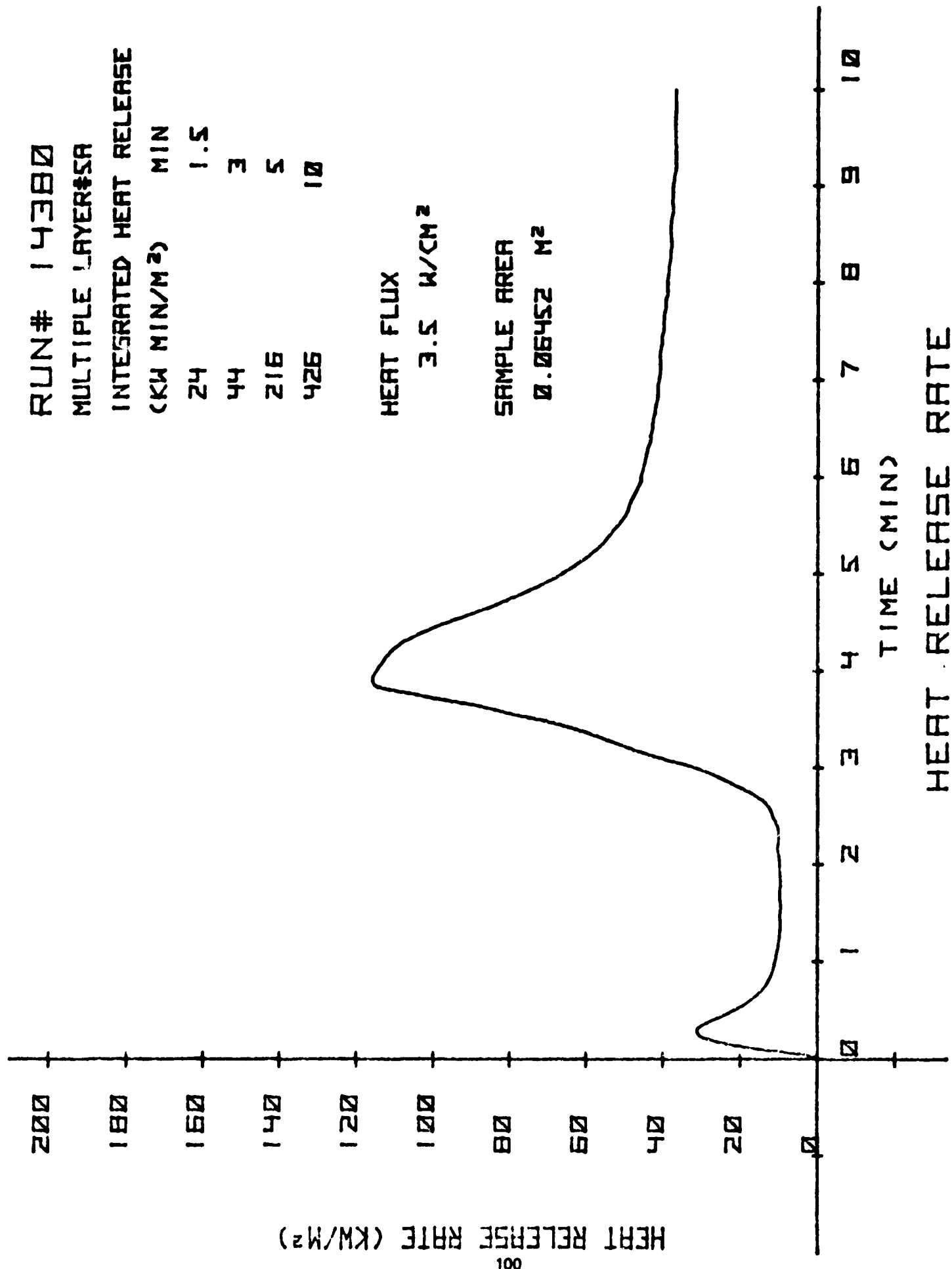
426 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.06452 M²



HEAT RELEASE RATE

RUN# 0000

MULTIPLE LAYER#1

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

103 1.5

241 3

403 5

586 10

HEAT FLUX

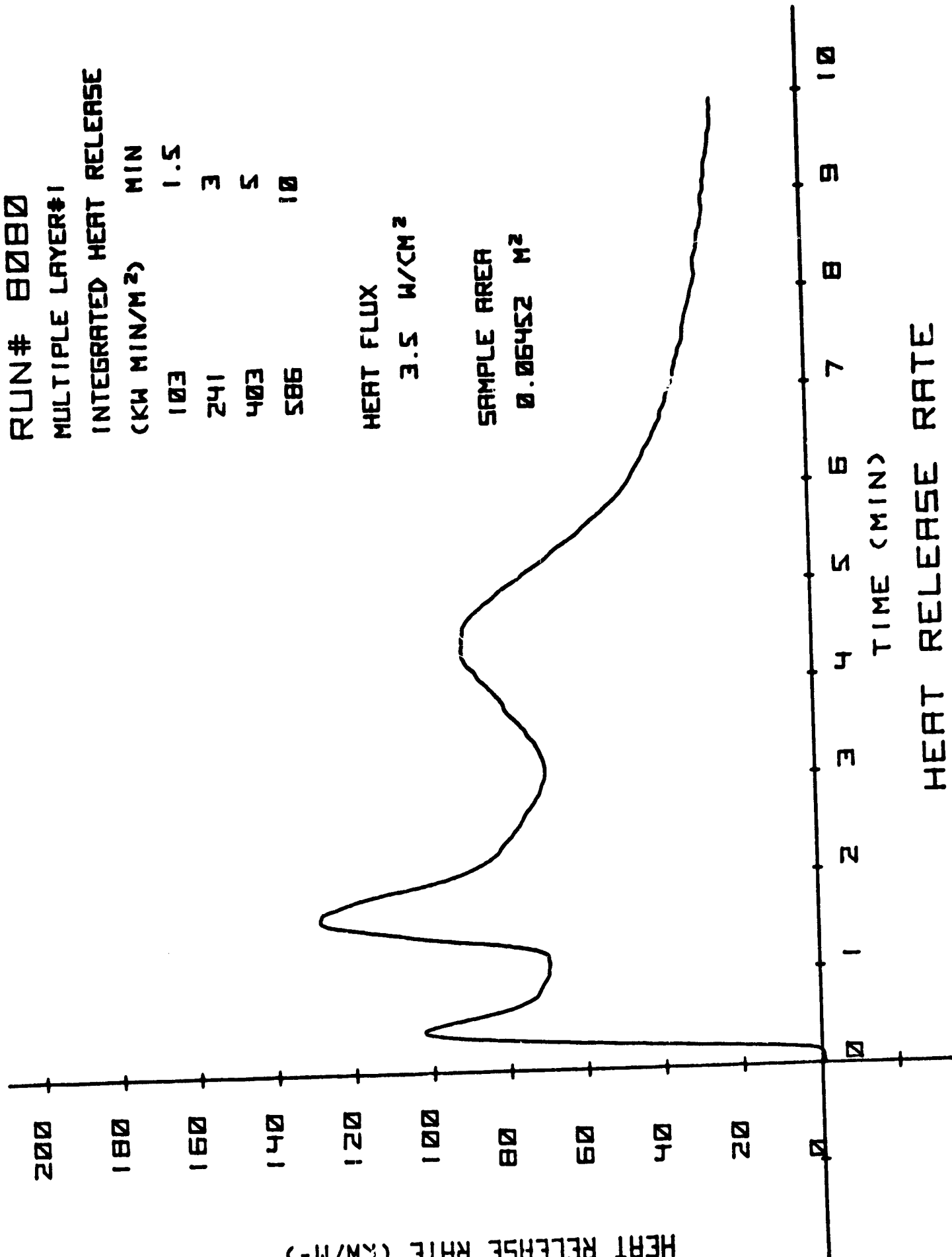
3.5 W/CM²

SAMPLE AREA

0.06452 M²

HEAT RELEASE RATE (KW/M²)

101



TIME (MIN)

HEAT RELEASE RATE

RUN# 0180

MULTIPLE LAYER#2

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

61 1.5

136 3

365 5

651 10

HEAT FLUX

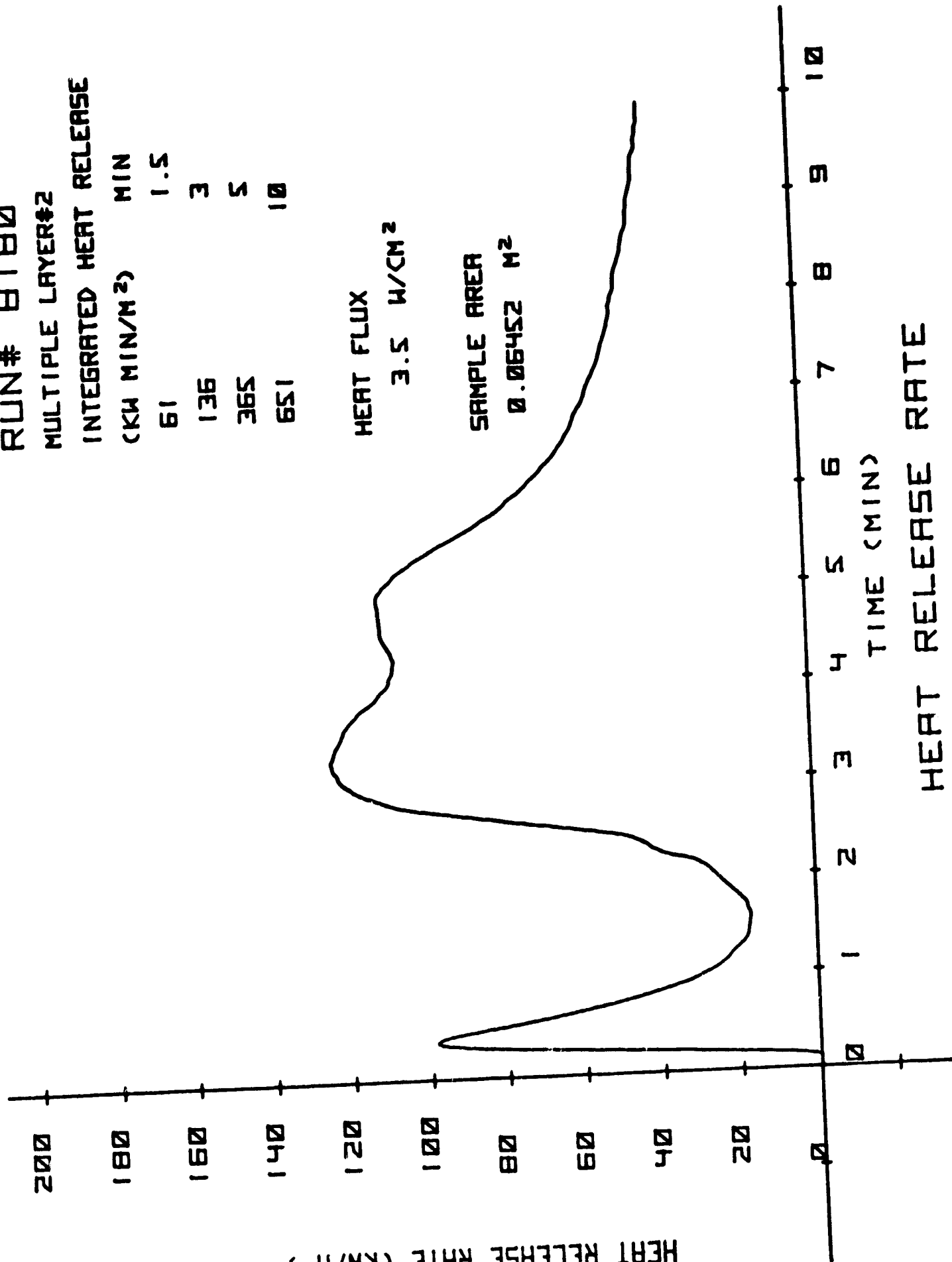
3.5 W/CM²

SAMPLE AREA

0.06452 M²

HEAT RELEASE RATE (KW/M²)

102



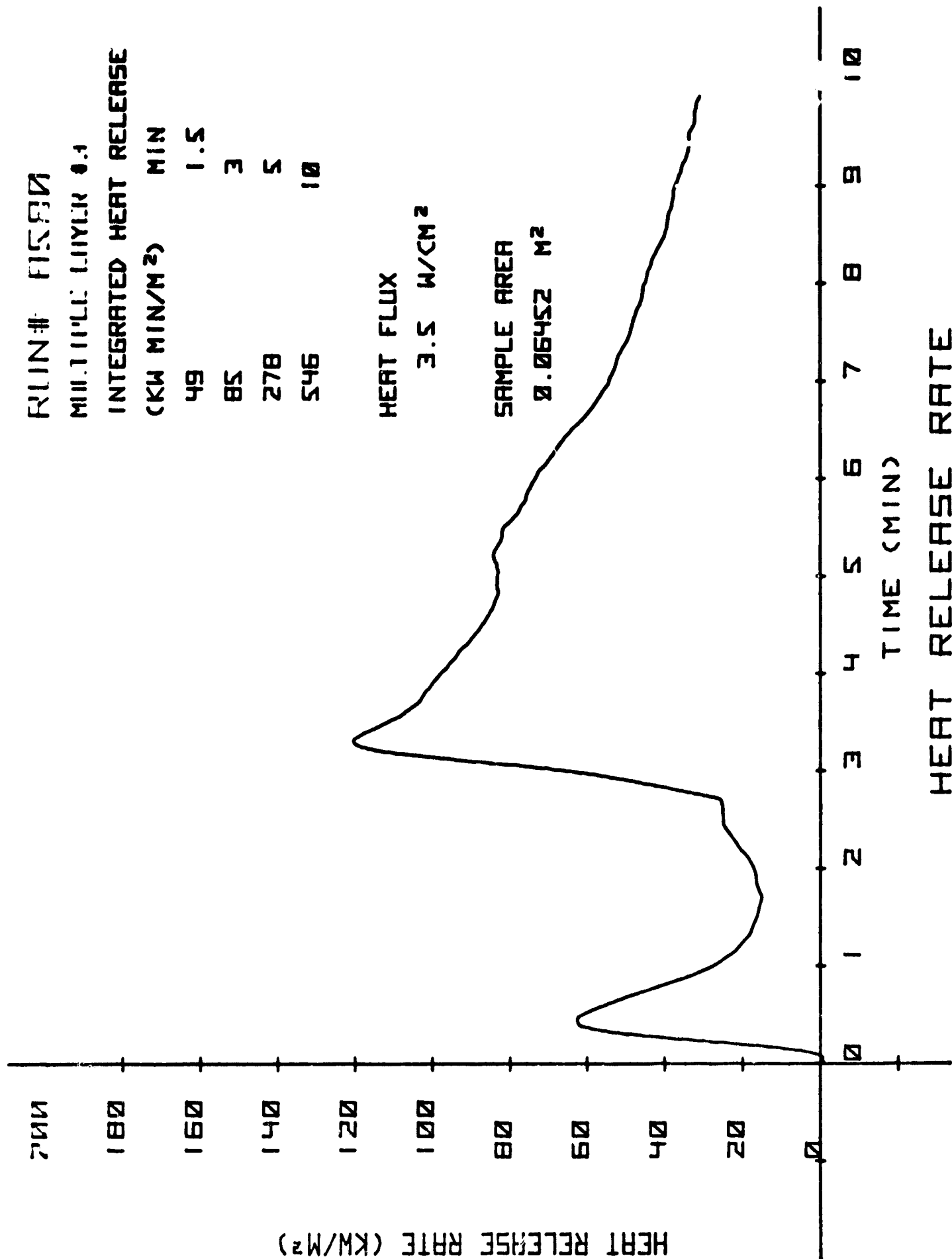
TIME (MIN)

HEAT RELEASE RATE

RUN# F1580
 MULTIPLE LAYER 0.4
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 49 1.5
 85 3
 278 5
 546 10

HEAT FLUX
 3.5 W/CM²

SAMPLE AREA
 0.06452 M²



HEAT RELEASE RATE

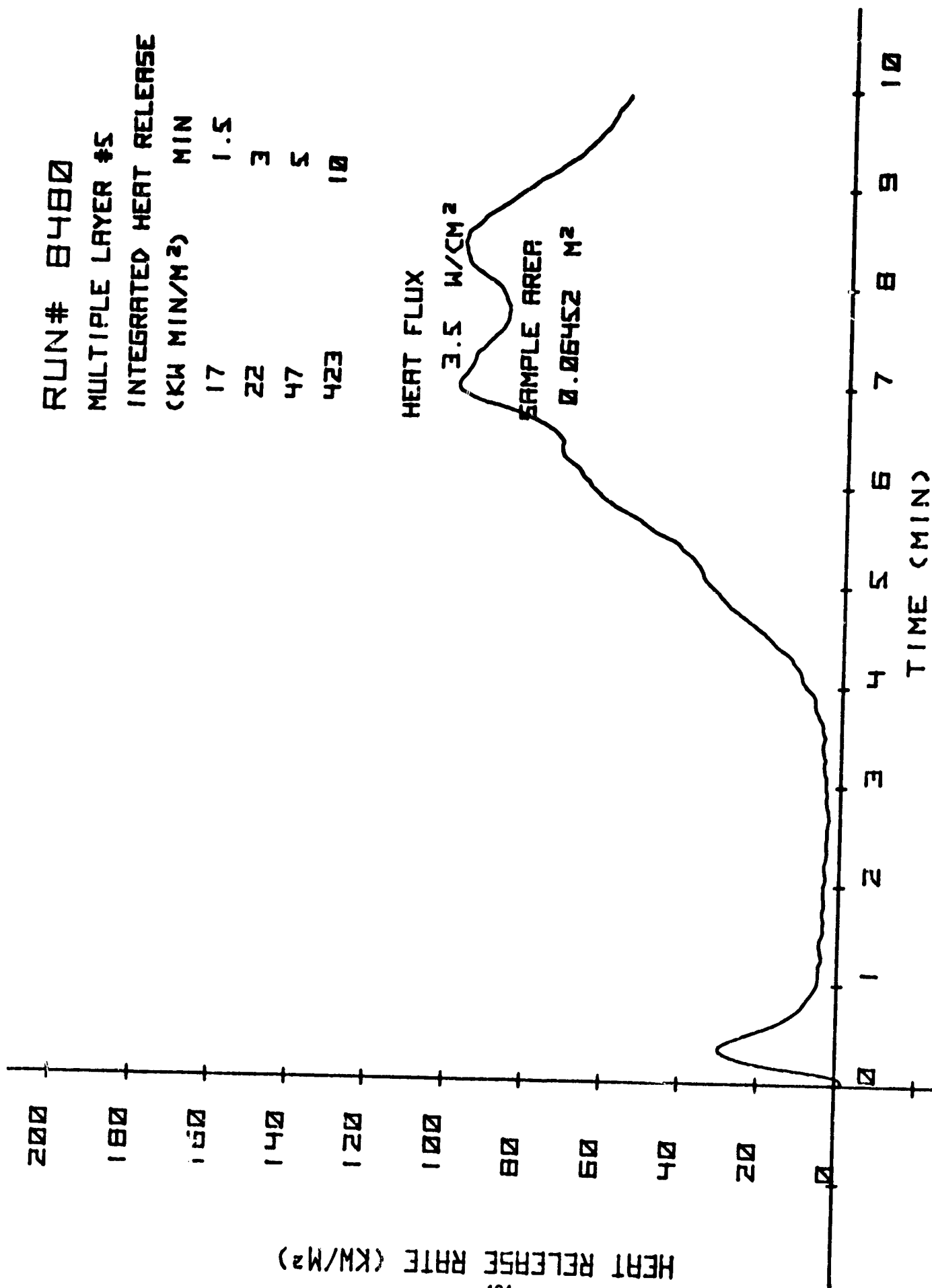
RUN# 8480

MULTIPLE LAYER #5

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

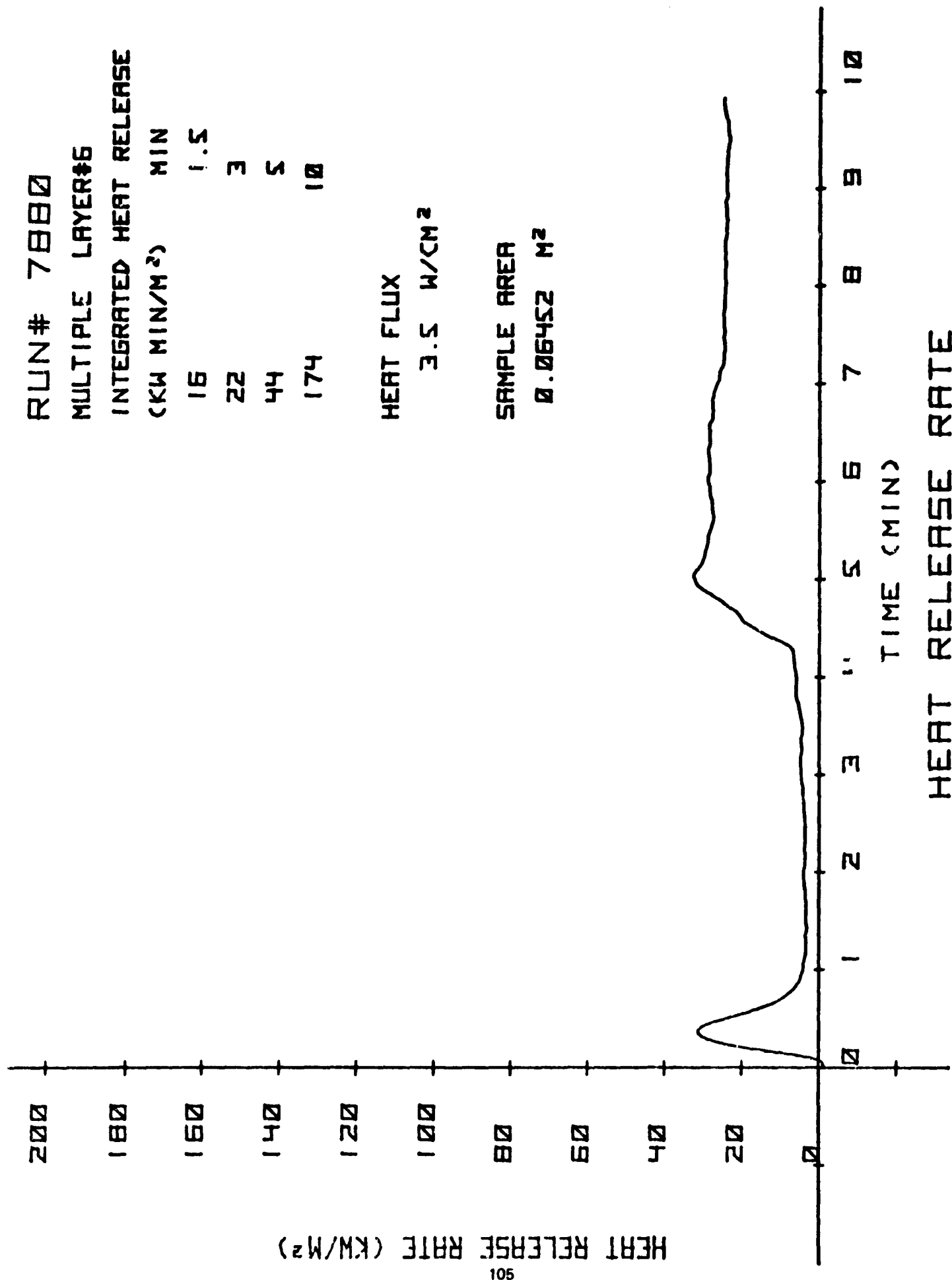
| | |
|-----|-----|
| 17 | 1.5 |
| 22 | 3 |
| 47 | 5 |
| 423 | 10 |



RUN# 7880
 MULTIPLE LAYER#6
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 16 1.5
 22 3
 44 5
 174 10

HEAT FLUX
 3.5 W/CM²

SAMPLE AREA
 0.06452 M²



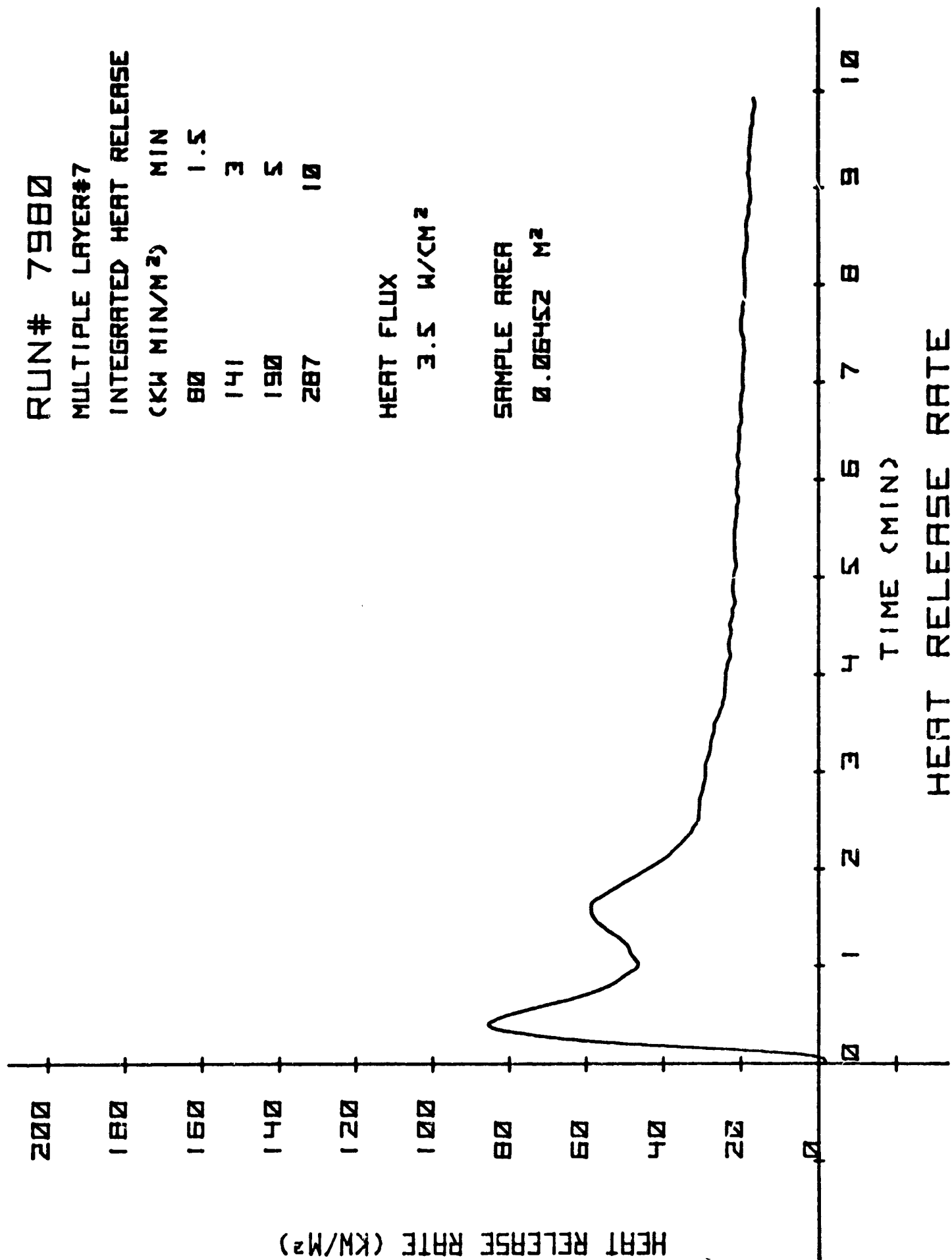
HEAT RELEASE RATE

HEAT RELEASE RATE (KW/M²)

RUN# 7980
 MULTIPLE LAYER#7
 INTEGRATED HEAT RELEASE
 (KW MIN/M²) MIN
 80 1.5
 141 3
 190 5
 287 10

HEAT FLUX
 3.5 W/CM²

SAMPLE AREA
 0.06452 M²



HEAT RELEASE RATE

RUN# 14480

MULTIPLE LAYER#8

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

81 1.5

197 3

273 5

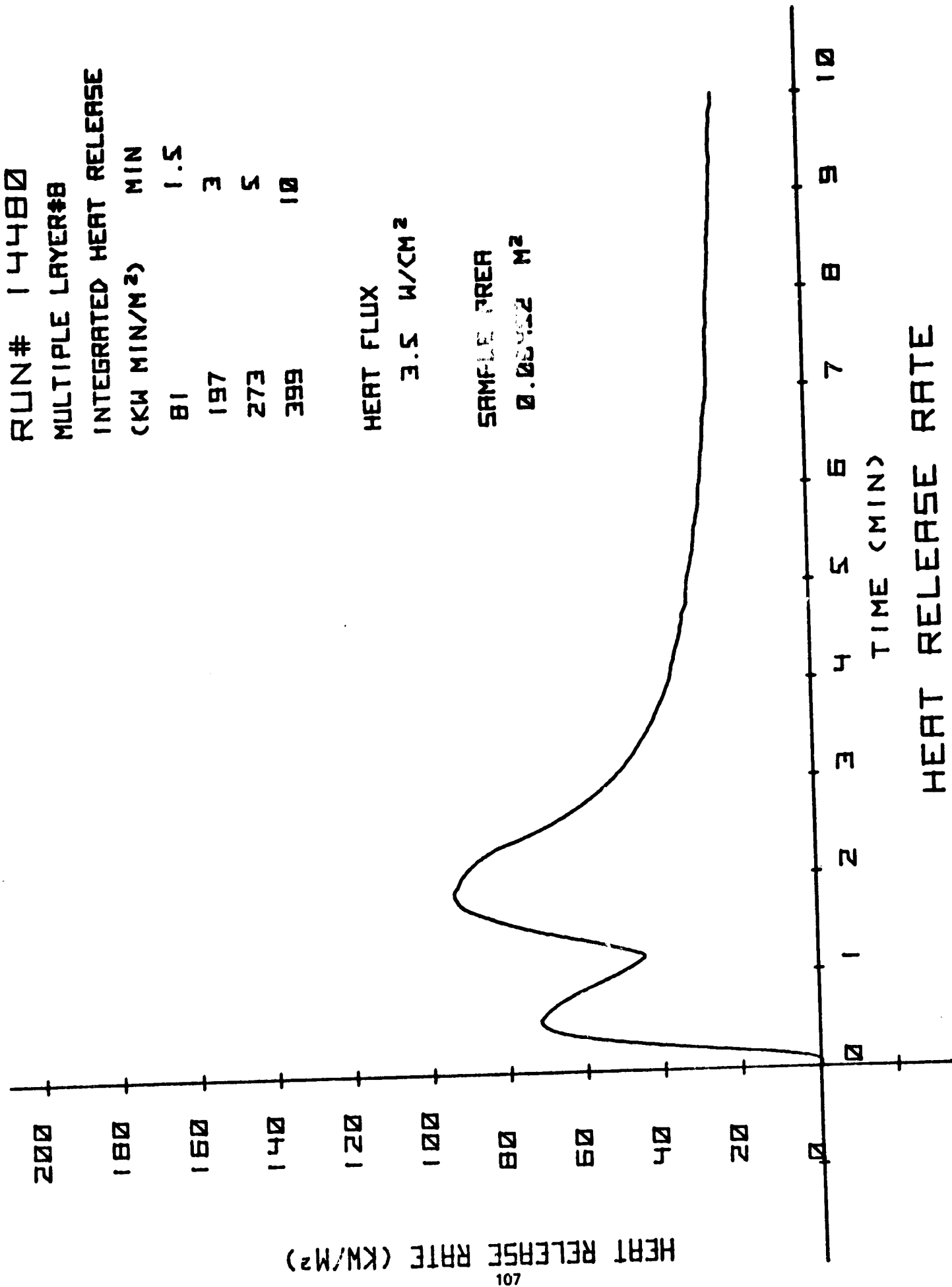
399 10

HEAT FLUX

3.5 W/CM²

SAMPLE PREP

0.05922 M²



RUN# 0300

MULTIPLE LAYER #9

INTEGRATED HEAT RELEASE

(KW MIN/M²) MIN

55 1.5

75 3

186 5

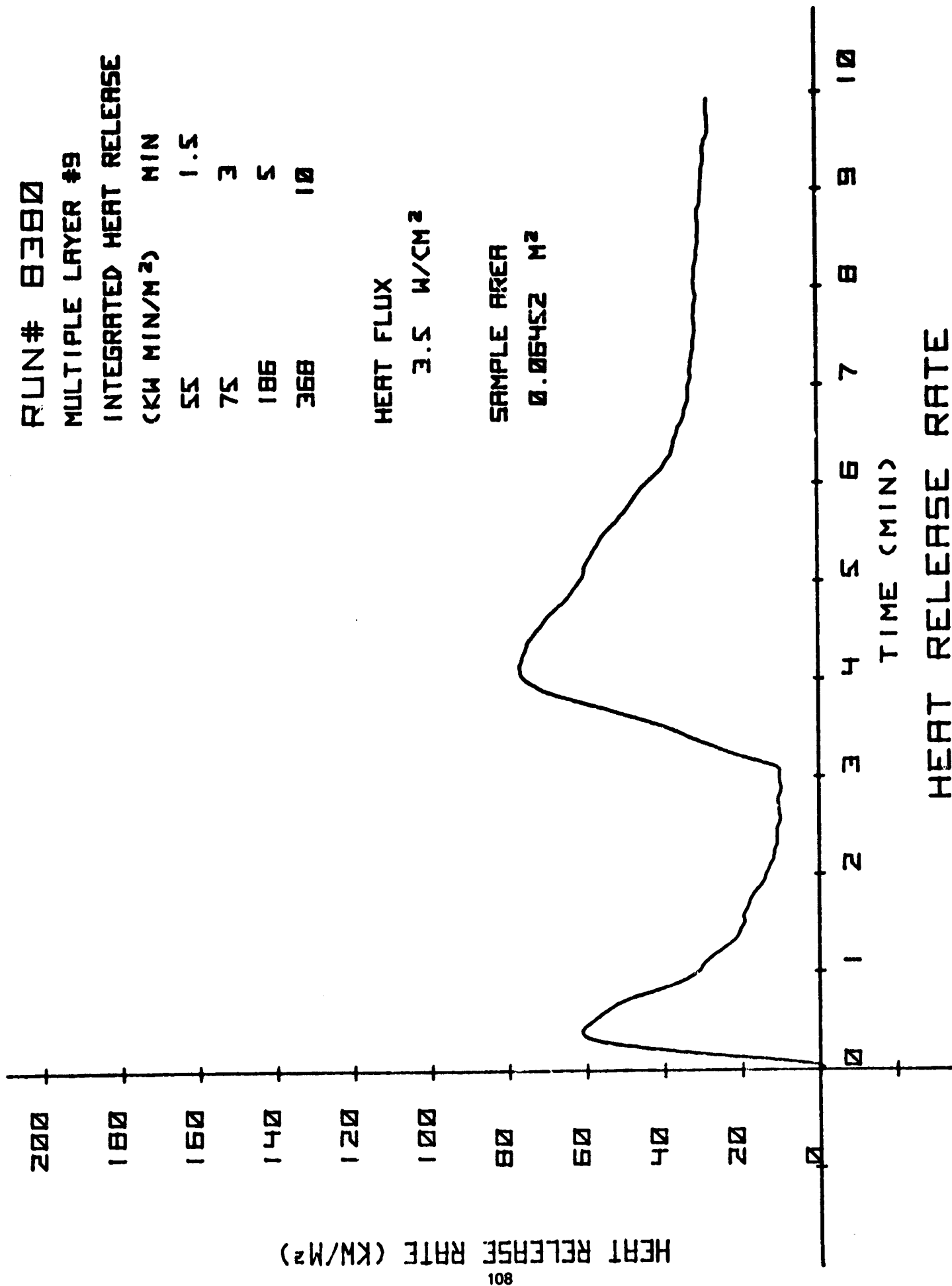
368 10

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.06452 M²

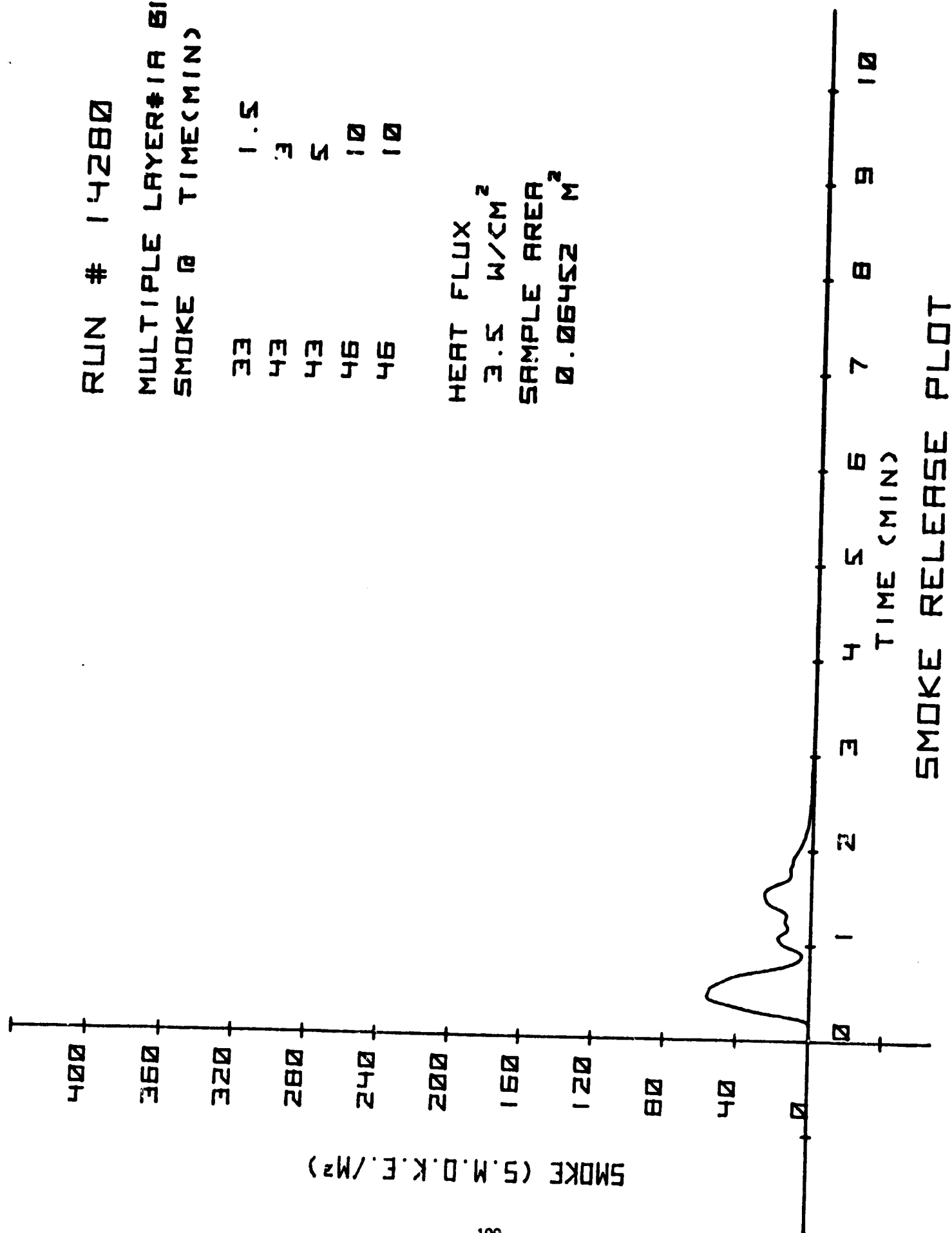


RUN # 14280

MULTIPLE LAYER#1A BI
SMOKE 0 TIME(MIN)

| | |
|----|-----|
| 33 | 1.5 |
| 43 | 3 |
| 43 | 5 |
| 46 | 10 |
| 46 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²

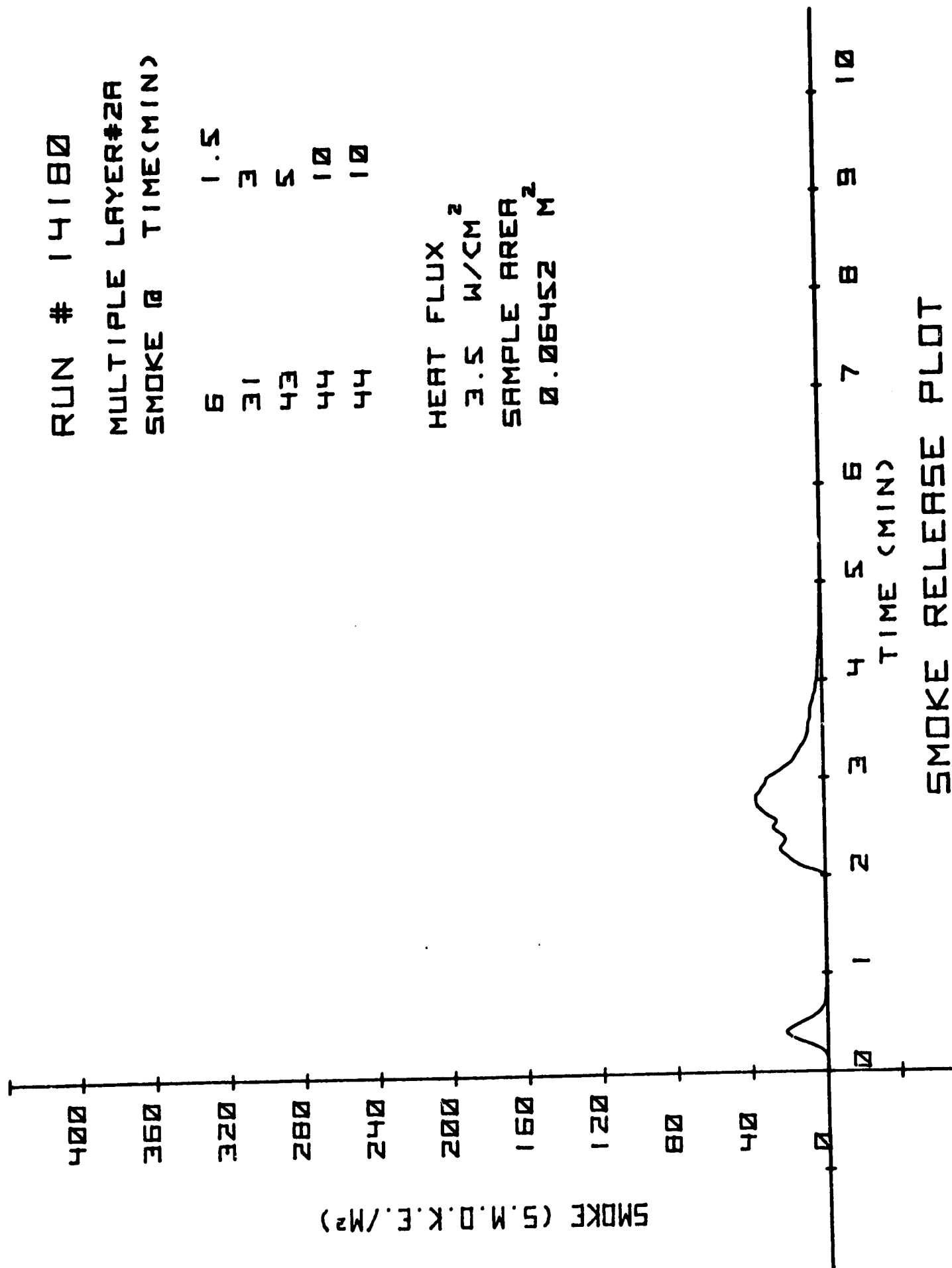


RUN # 14180

MULTIPLE LAYER#2A
SMOKE @ TIME(MIN)

| | |
|----|-----|
| 6 | 1.5 |
| 31 | 3 |
| 43 | 5 |
| 44 | 10 |
| 44 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²



RUN # 11980

MULTIPLE LAYER#4A

SMOKE @ TIME(MIN)

| | |
|-----|-----|
| 2 | 1.5 |
| 4 | 3 |
| 6 | 5 |
| 215 | 10 |
| 215 | 10 |

HEAT FLUX

3.5 W/CM²

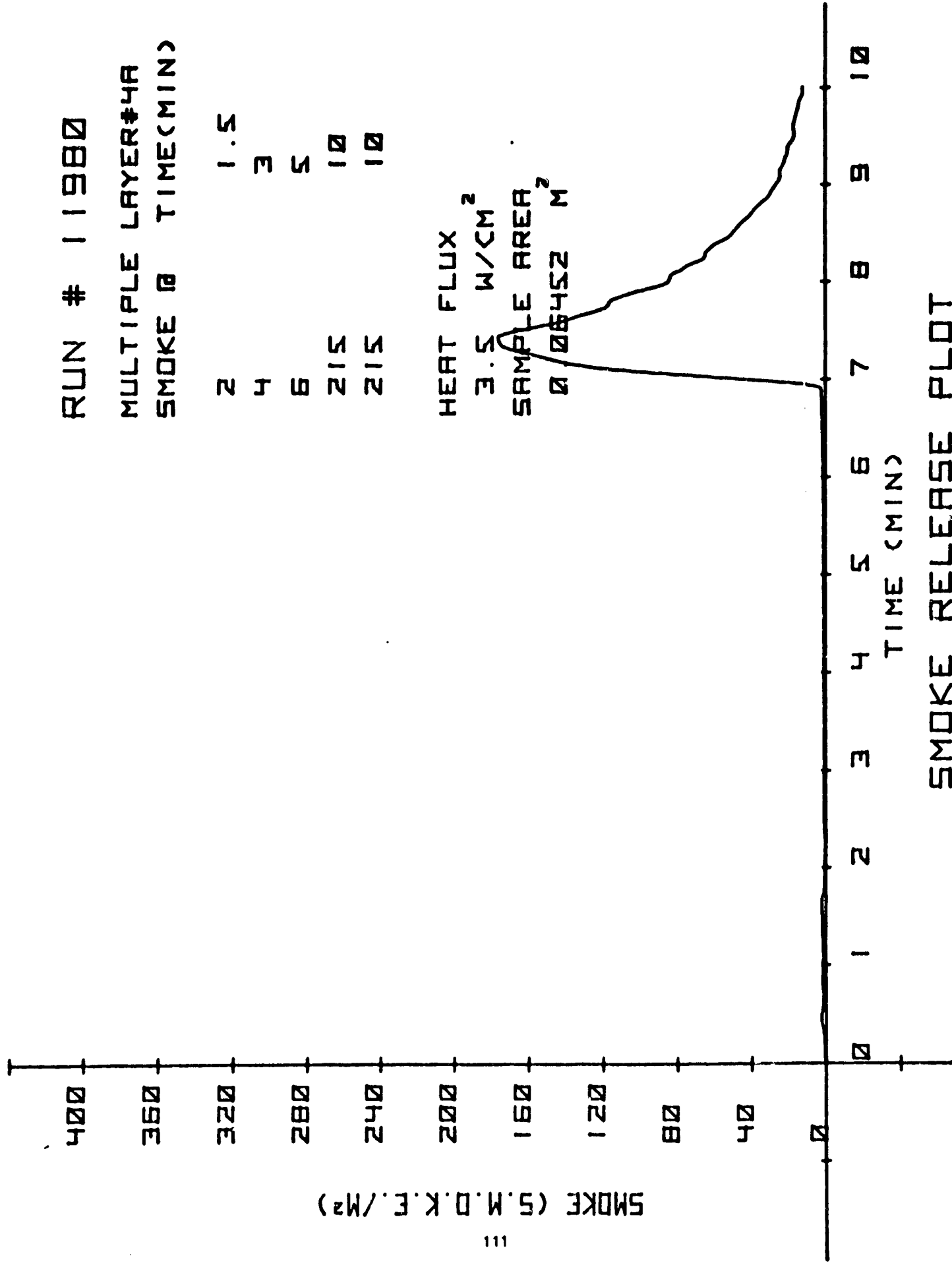
SAMPLE AREA

0.06452 M²

SMOKE (S.M.D.K.E./M²)

TIME (MIN)

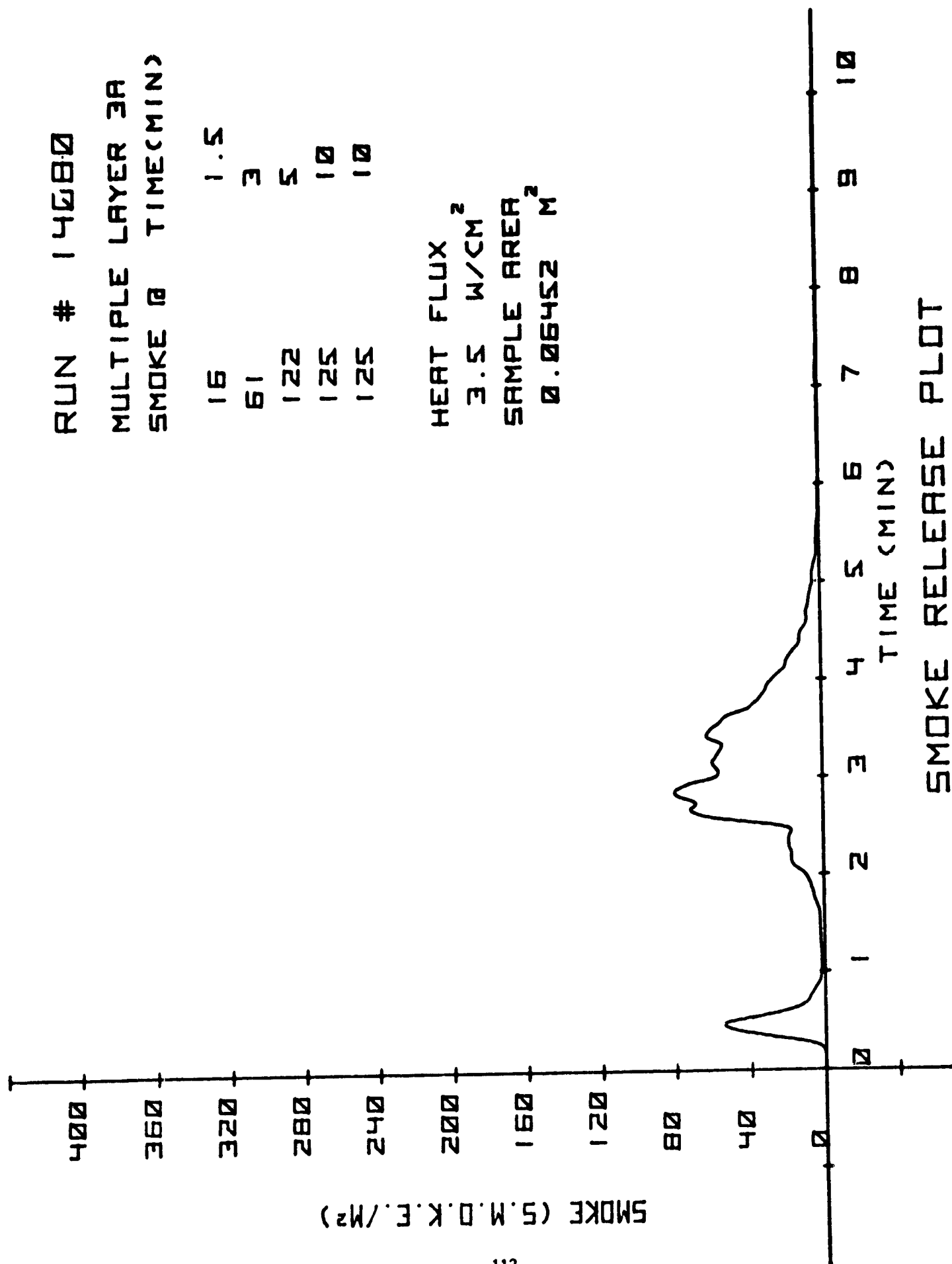
SMOKE RELEASE PLOT



RUN # 14680
 MULTIPLE LAYER 3A
 SMOKE R TIME(MIN)

| | |
|-----|-----|
| 16 | 1.5 |
| 61 | 3 |
| 122 | 5 |
| 125 | 10 |
| 125 | 10 |

HEAT FLUX
 3.5 W/CM²
 SAMPLE AREA
 0.06452 M²

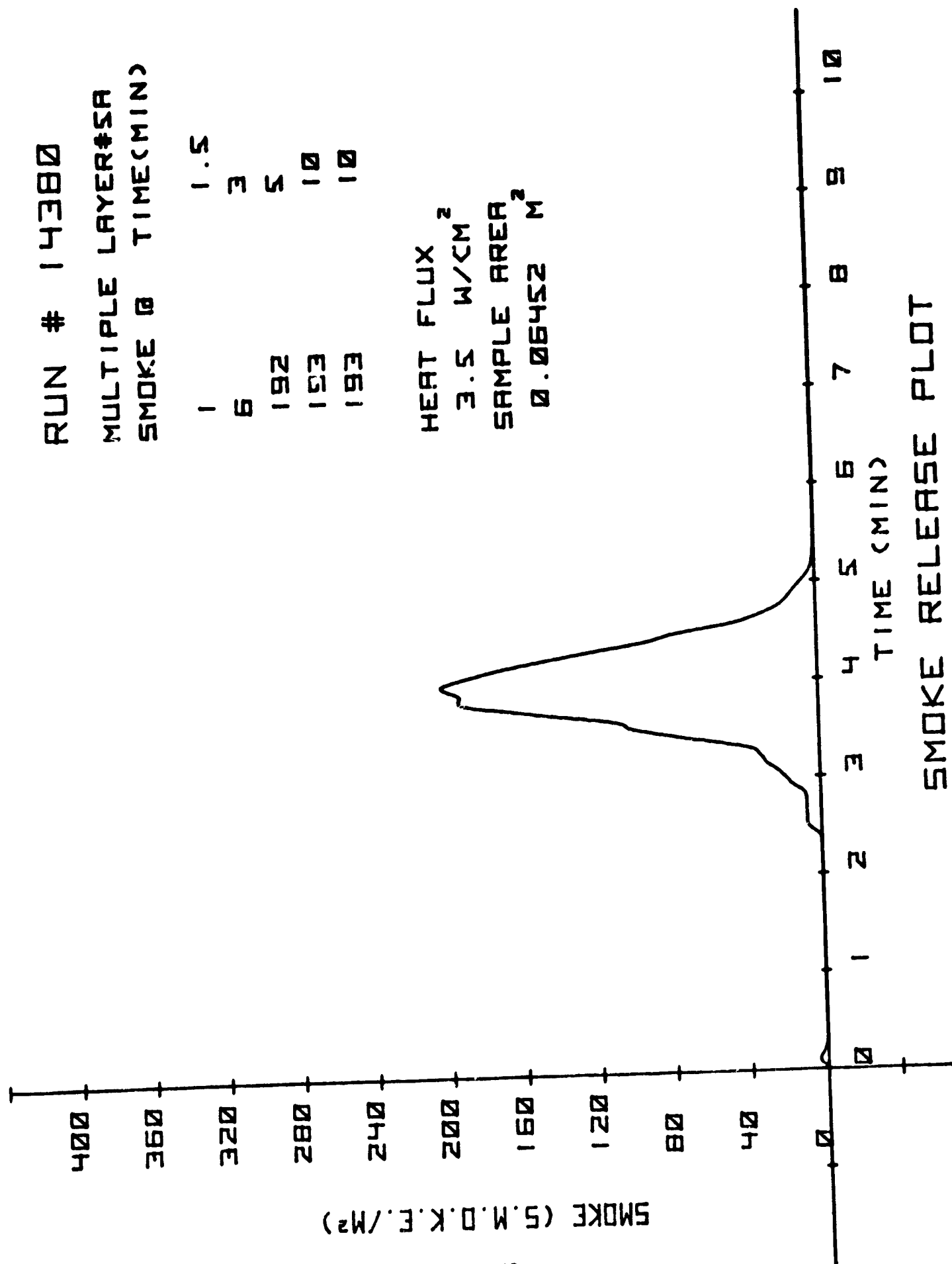


RUN # 14380

MULTIPLE LAYER#5A
SMOKE @ TIME(MIN)

| | |
|-----|-----|
| 1 | 1.5 |
| 6 | 3 |
| 192 | 5 |
| 193 | 10 |
| 193 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA²
0.06452 M²

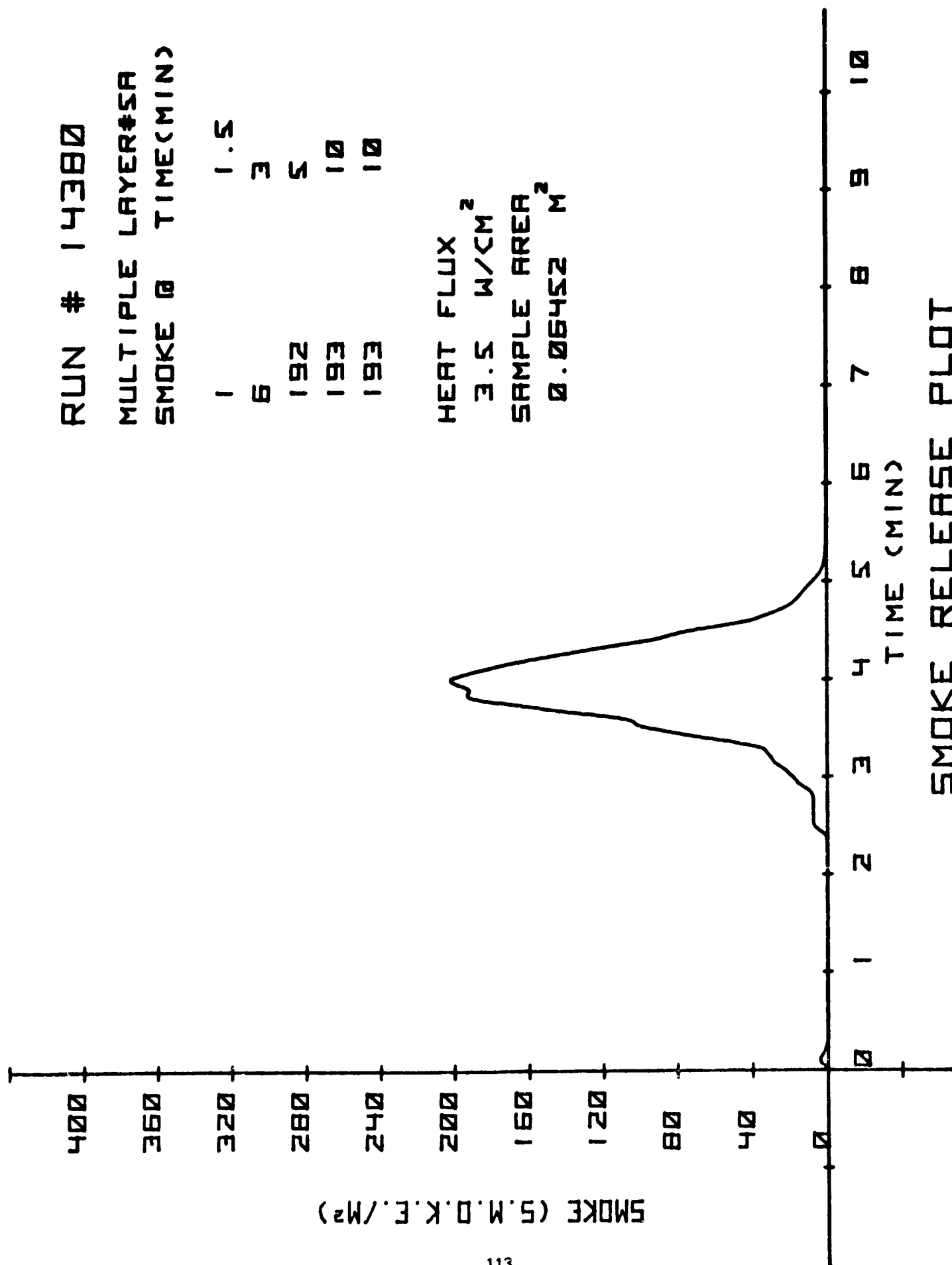


RUN # 14380

MULTIPLE LAYER#SA
SMOKE @ TIME(MIN)

| | |
|-----|-----|
| 1 | 1.5 |
| 6 | 3 |
| 192 | 5 |
| 193 | 10 |
| 193 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²

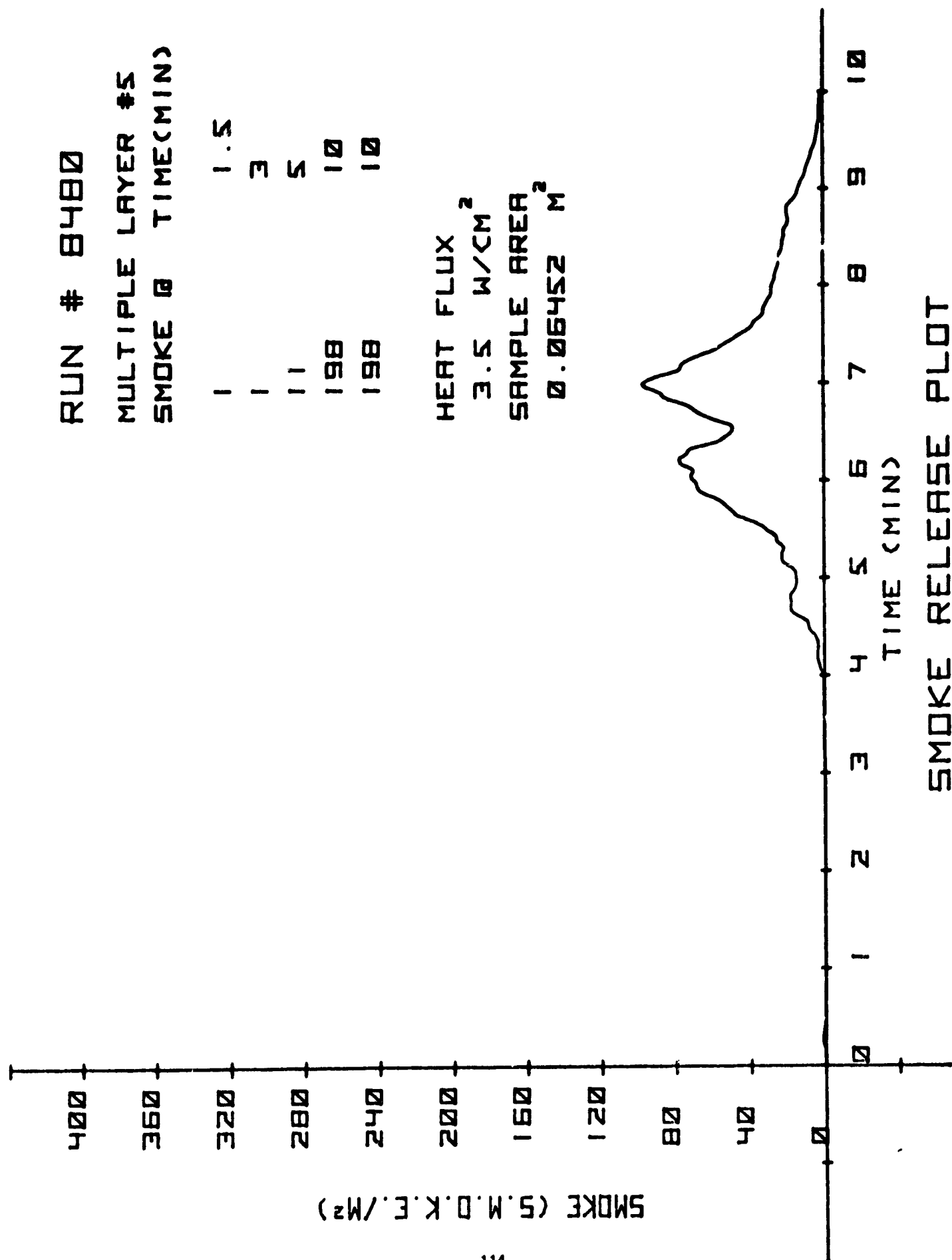


RUN # 8480

MULTIPLE LAYER #5
SMOKE @ TIME(MIN)

| | |
|-----|-----|
| 1 | 1.5 |
| 1 | 3 |
| 11 | 5 |
| 198 | 10 |
| 198 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²



RUN # 0180

MULTIPLE LAYER#2

SMOKE @ TIME(MIN)

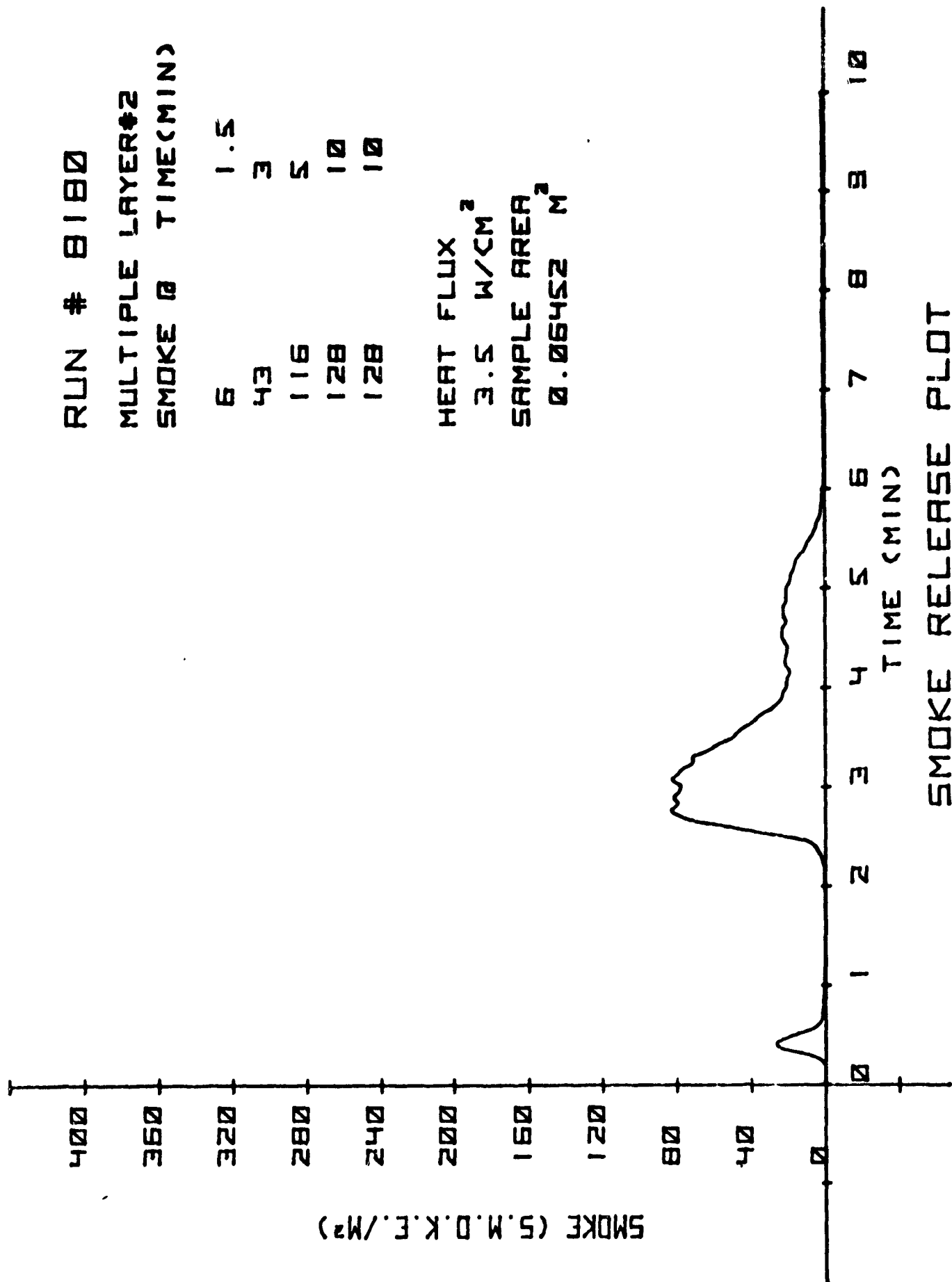
| | |
|-----|-----|
| 6 | 1.5 |
| 43 | 3 |
| 116 | 5 |
| 128 | 10 |
| 128 | 10 |

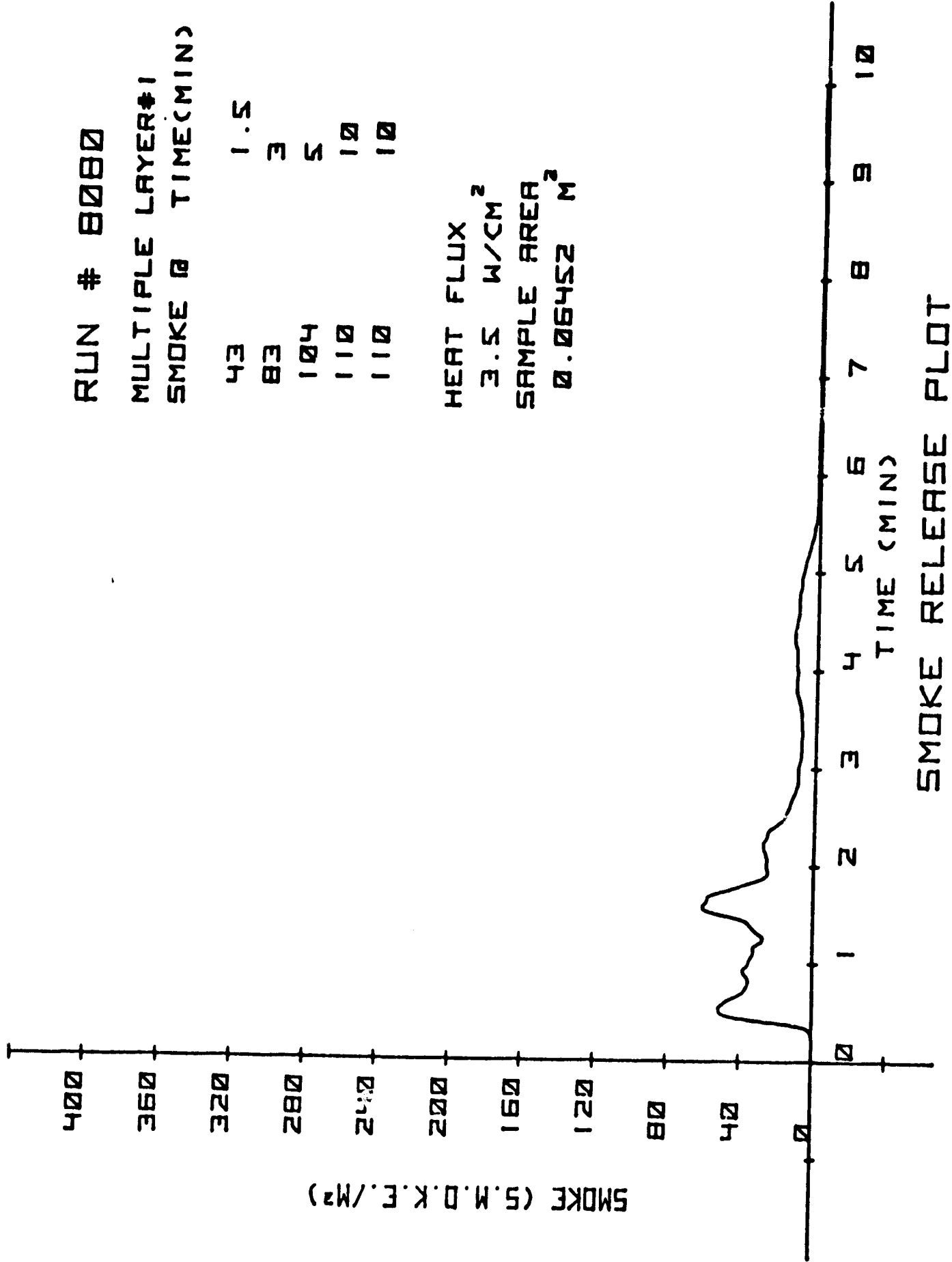
HEAT FLUX

3.5 W/CM²

SAMPLE AREA,

0.06452 M²



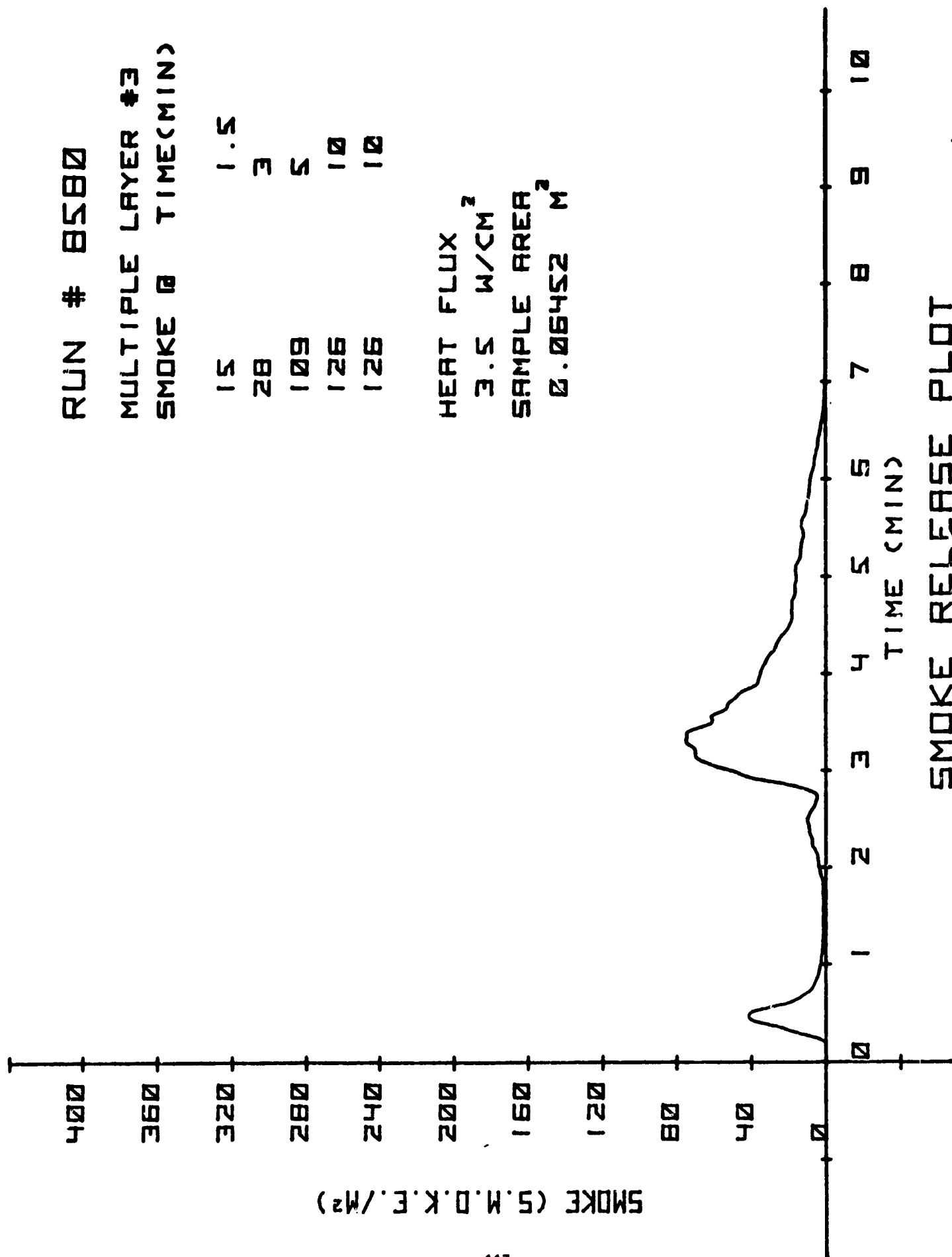


RUN # 8580

MULTIPLE LAYER #3
SMOKE @ TIME(MIN)

| | |
|-----|-----|
| 15 | 1.5 |
| 28 | 3 |
| 109 | 5 |
| 126 | 10 |
| 126 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²



SMOKE RELEASE PLOT

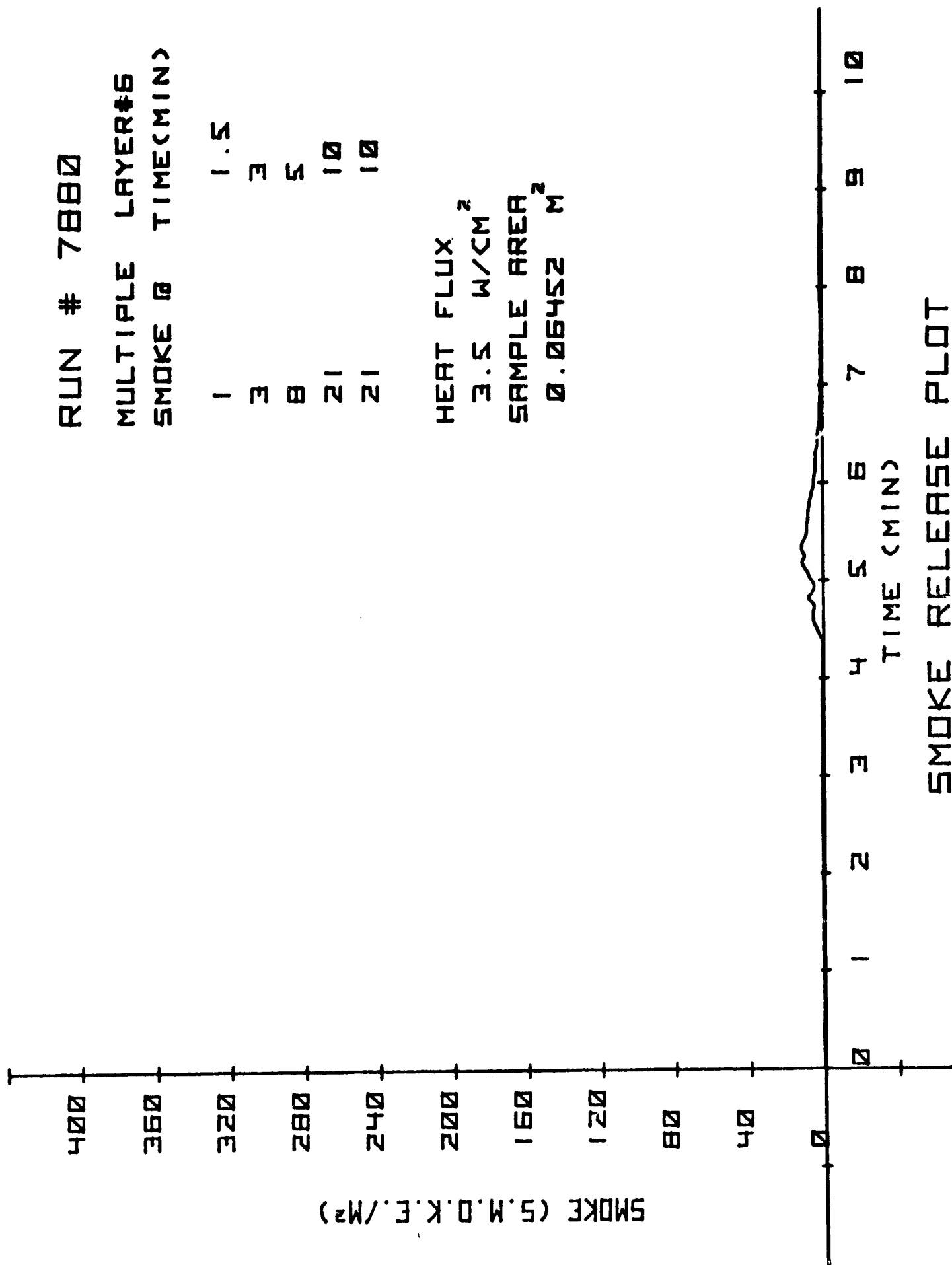
RUN # 7880

MULTIPLE LAYER#6

SMOKE @ TIME(MIN)

| | |
|----|-----|
| 1 | 1.5 |
| 3 | 3 |
| 8 | 5 |
| 21 | 10 |
| 21 | 10 |

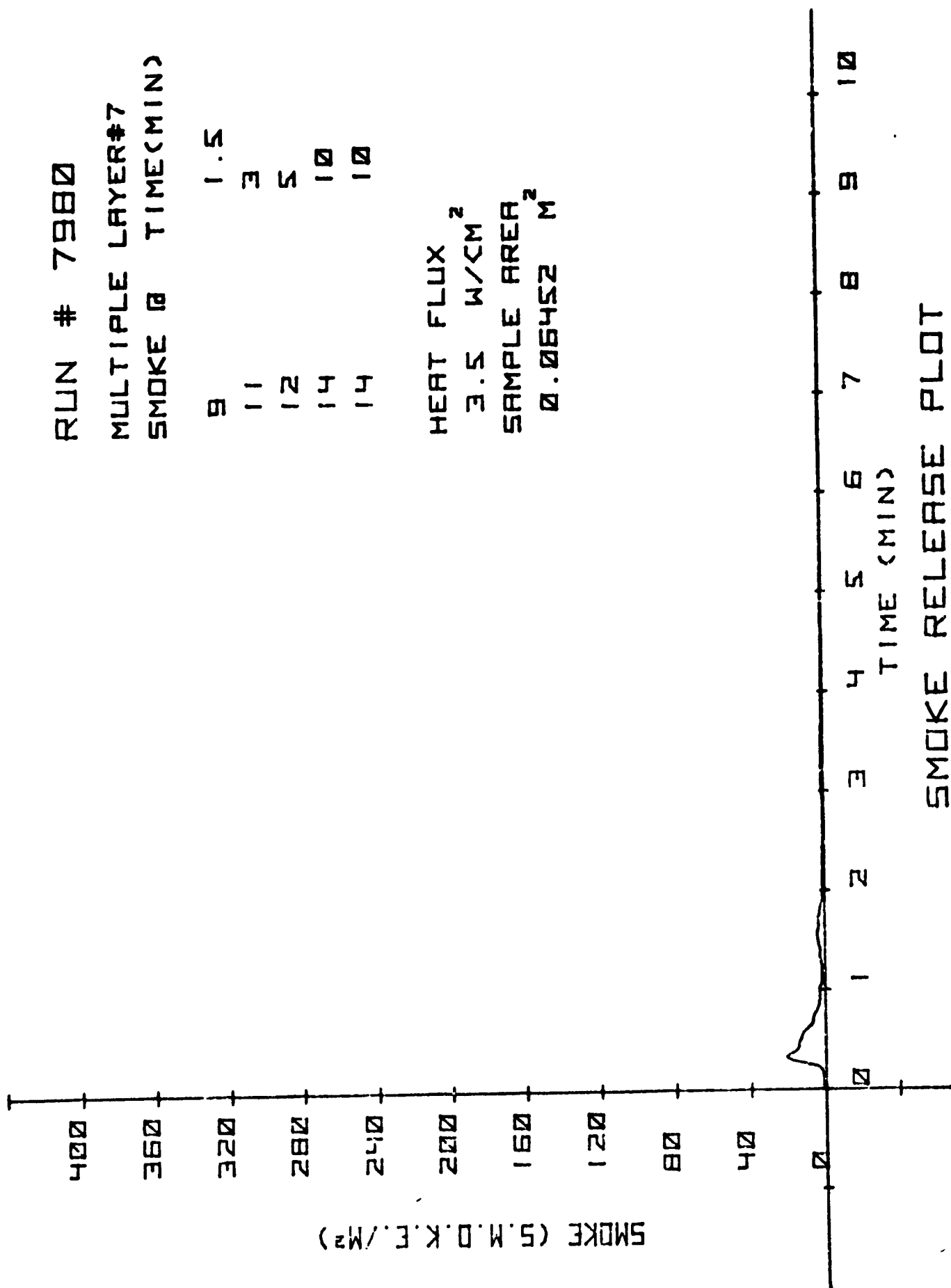
HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²



RUN # 7980
 MULTIPLE LAYER#7
 SMOKE Q TIME(MIN)

| | |
|----|-----|
| 9 | 1.5 |
| 11 | 3 |
| 12 | 5 |
| 14 | 10 |
| 14 | 10 |

HEAT FLUX
 3.5 W/CM²
 SAMPLE AREA
 0.06452 M²



RUN # 14480

MULTIPLE LAYER#8

SMOKE @ TIME(MIN)

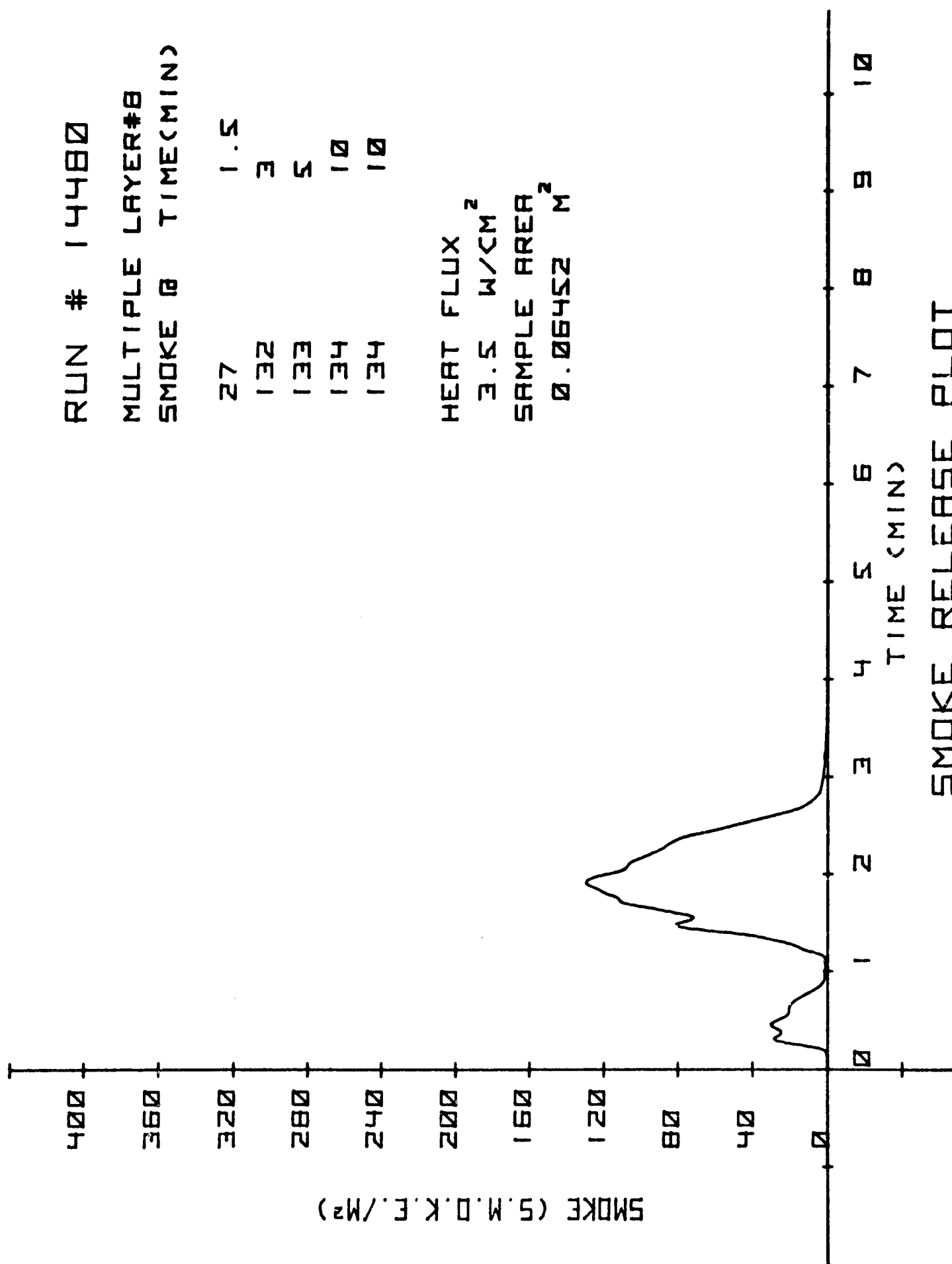
| | |
|-----|-----|
| 27 | 1.5 |
| 132 | 3 |
| 133 | 5 |
| 134 | 10 |
| 134 | 10 |

HEAT FLUX

3.5 W/CM²

SAMPLE AREA

0.06452 M²



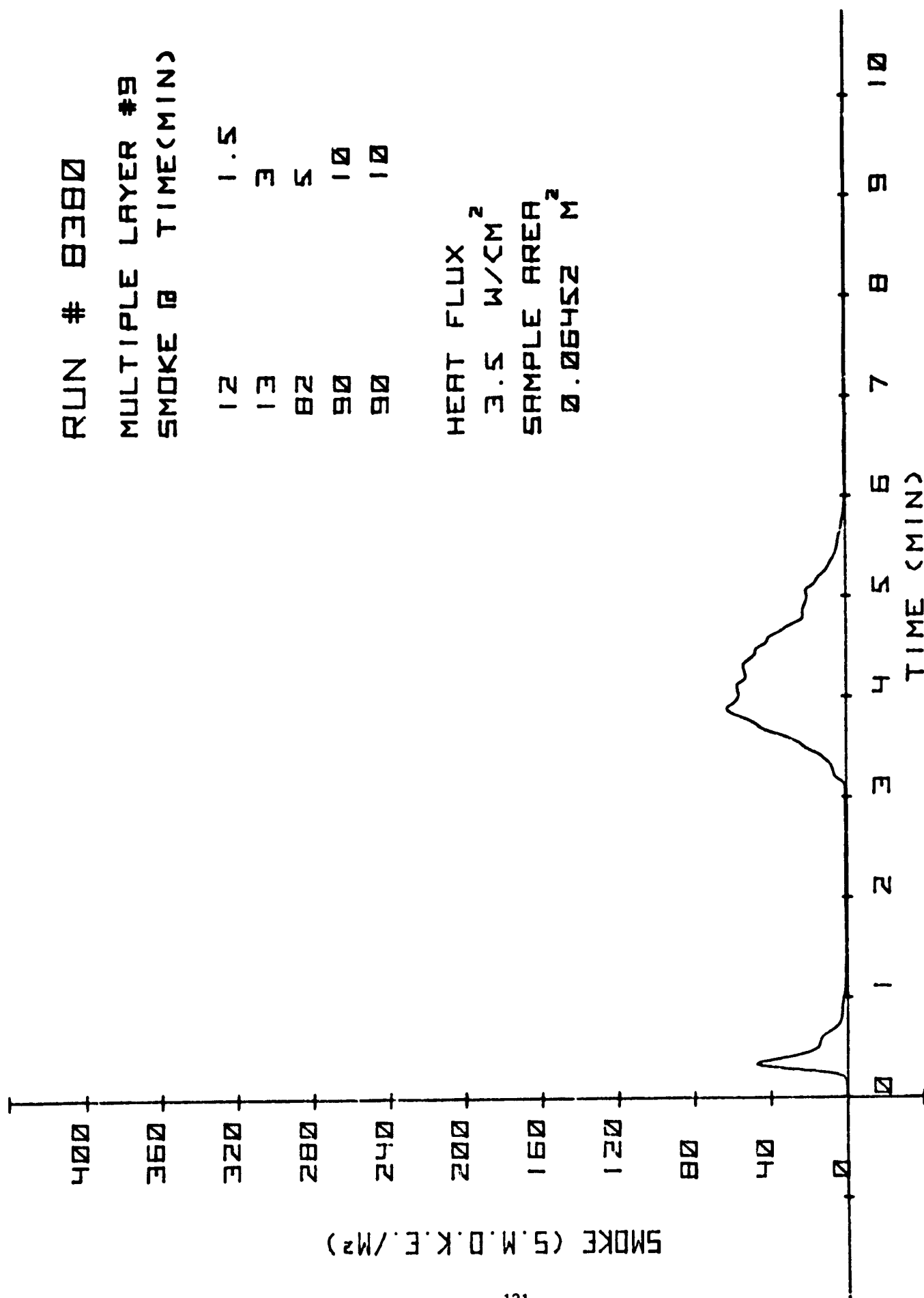
RUN # 0380

MULTIPLE LAYER #9

SMOKE 0 TIME(MIN)

| | |
|----|-----|
| 12 | 1.5 |
| 13 | 3 |
| 02 | 5 |
| 00 | 10 |
| 00 | 10 |

HEAT FLUX
3.5 W/CM²
SAMPLE AREA
0.06452 M²



SMOKE RELEASE PLOT